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DRILLING FOR ANSWERS: OIL COMPANY PROFITS, RUNAWAY PRICES AND THE PURSUIT OF ALTERNATIVES

HEARING

BEFORE THE

SELECT COMMITTEE ON
ENERGY INDEPENDENCE
AND GLOBAL WARMING
HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

SECOND SESSION

APRIL 1, 2008

Serial No. 110–30

Printed for the use of the Select Committee on
Energy Independence and Global Warming

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DRILLING FOR ANSWERS: OIL COMPANY PROFITS, RUNAWAY PRICES AND THE PURSUIT OF ALTERNATIVES

TUESDAY, APRIL 1, 2008

HOUSE OF REPRESENTATIVES,
SELECT COMMITTEE ON ENERGY INDEPENDENCE AND
GLOBAL WARMING,
Washington, DC.

The Committee met, pursuant to call, at 12:00 p.m., in Room 210 Cannon House Office Building, Hon. Edward Markey [chairman of the Committee] presiding.

Present: Representatives Markey, Blumenauer, Inslee, Larson, Solis, Herseth Sandlin, Cleaver, Hall, McNerney, Sensenbrenner, Shadegg, Walden, Miller, Sullivan, and Blackburn.

Staff present: Morgan Gray.

The Chairman. The Select Committee on Energy Independence and Global Warming is called to order, and we welcome all of you to our very important hearing today.

Yesterday Americans saw that the price of gasoline hit a record high price. Today on April Fool's Day, consumers all over America are hoping that the top executives from the five largest oil companies will tell us that these soaring gas prices are just part of some elaborate hoax.

Unfortunately, it is not a joke. For nearly eight years this administration's energy policy has been in the tank. Shortly after President Bush took office, the price of oil was under $20. A few weeks ago oil reached an all time record high of $111, and currently trades at about $100 a barrel.

During the same period, the price of gasoline has nearly tripled from $1.11 a gallon in 2002, to yesterday's all time high when it hit $3.29 a gallon. And as we approach the summer driving season, skyrocketing gas prices are likely to soar even higher.

Each week American consumers go to the gas pump and pay the price for this administration's failed energy policy. Twenty percent of all households in America make less than $20,000 a year. With gas prices at $3.29 a gallon, the poorest 20 percent of American households are spending nearly ten percent of their income just on gasoline.

American consumers also know that the major oil companies are reaping a major financial windfall. Big oil's profits have more than quadrupled over the last six years. Just last year alone Exxon Mobil recorded more than $40 billion in profit, the greatest corporate profit in history, and the five companies sitting before us today netted a combined $123 billion in profit in 2007.

And what is the oil industry doing with all of this profit? Unfortunately, it goes as much to financial engineering as to renewal engineering. Last year the five largest oil companies spent more than $50 billion on schemes to prop up the price of their stock, and as they rake in the profits at a record clip, the major oil companies supported by the Bush administration are opposing legislation that would take $18 billion in tax breaks they currently receive and redirect it to renewable fuels and clean energy.

In April of 2005, President Bush said, "With $55 a barrel oil, we don't need incentives for oil and gas companies to explore," and that was true in 2005. With the price of oil now doubled and our planet's thermometer rising, this administration must end its opposition to the renewable energy incentive package that the House passed last month.

So on April Fool's Day the biggest joke of all is being played on American families by big oil while using every trick in the book to keep billions in federal tax subsidies even as they rake in record profits.

Three things must happen immediately in order to insure the consumers can begin to get relief from high prices. First, the poorest Americans are now spending an average of ten percent of their income to pay for gasoline. We need the companies here today to make a similar commitment to American families and pledge to invest at least ten percent of their profits in renewable energy and biofuels, to develop alternatives that will help consumers.

Second, your companies and the Bush administration must support, not oppose, legislation, that will unleash the renewable revolution we need in order to become energy independent and cut global warming emissions.

And finally, the Bush administration must stop filling the strategic petroleum reserve during periods of high prices in order to send a signal to the market and oil speculators that Americans will not be held hostage by those high prices. For too long this administration's energy policy has led to tax breaks for big oil and tough breaks for American families. American consumers should not have to break the bank to fill the tank.

The American people deserve answers, and it is time for big oil to go on record about these record prices.

And now I would like to recognize the Ranking Member of the Select Committee, the gentleman from Wisconsin, Mr. Sensenbrenner.

[The prepared statement of Mr. Markey follows:]

THE SELECT COMMITTEE ON
ENERGY INDEPENDENCE AND GLOBAL WARMING

Opening Statement for Chairman Edward J. Markey
"Drilling for Answers: Oil Company Profits, Runaway Prices and the Pursuit of Alternatives"
Select Committee on Energy Independence and Global Warming
April 1, 2008

Yesterday, Americans saw that the price of gas hit a record high price. Today, on April Fool's Day, consumers all over America are hoping that the top executives from the five largest oil companies will tell us that these soaring gas prices are just part of some elaborate hoax.

Unfortunately, it's not a joke. For nearly eight years this administration's energy policy has been in the tank.

Shortly after President Bush took office, the price of oil was under $20. A few weeks ago, oil reached an all-time record high of $111 and currently trades over $100.

During this same period, the price of gasoline has nearly tripled -- from $1.11 a gallon in 2002 to yesterday's all-time high, when it hit yet another record of $3.29 a gallon.

And as we approach the summer driving season, skyrocketing gas prices are likely far from over.

Each week, American consumers go to the gas pump and pay the price for this administration's failed energy policy. 20 percent of all households in America make less than $20,000 a year. With gas prices at $3.29 per gallon, the poorest 20 percent of American households are spending nearly 10 percent of their income just on gasoline.

American consumers also know that the major oil companies are reaping a major financial windfall. Big Oil's profits have more than quadrupled over the last six years. Just last year alone, Exxon Mobil recorded more than $40 billion in profit -- the greatest corporate profit in history -- and the five companies sitting before us today netted a combined $123 billion.

And what is the oil industry doing with all this profit? Unfortunately, it goes as much to financial engineering as to renewable engineering. Last year, the five largest oil companies spent more than $50 billion on schemes to prop up the price of their stock.

And as they rake in profits at a record clip, the major oil companies, supported by the Bush administration, are opposing legislation that would take eighteen billion dollars in tax breaks they currently receive and redirect it to renewable fuels and clean energy.

In April of 2005, President Bush said "with $55 oil, we don't need incentives for oil and gas companies to explore." With the price of oil now doubled and our planet's thermometer rising, this Administration must end its opposition to the renewable energy incentive package that the House passed last month.

So on April Fool's Day, the biggest joke of all is being played on American families by Big Oil who are using every trick in the book to keep billions in federal tax subsidies, even as they rake in record profits.

Three things must happen immediately in order to ensure that consumers can begin to get relief from high prices. First, the poorest Americans are now spending an average of 10 percent of their income to pay for gasoline. We need the companies here today to make a similar commitment to American families and pledge to invest at least 10 percent of their profits in renewable energy and biofuels to develop alternatives that will help consumers.

Second, your companies and the Bush administration must support, not oppose, legislation that will unleash the renewable revolution we need to become energy independent and cut global warming emissions.

And finally, the Bush Administration must stop filling the Strategic Petroleum Reserve during periods of high prices in order to send a signal to the market and oil speculators that Americans won't be held hostage by high prices.

> For too long, this Administration's energy policy has led to tax breaks for Big Oil, and tough breaks for American families. American consumers shouldn't have to break the bank to fill the tank. The American people deserve answers and it is time for Big Oil to go on record about these record prices.

Mr. SENSENBRENNER. Thank you, Mr. Chairman.

Today's hearing is about high gas prices, and it is an issue that my Wisconsin constituents understand all too well. Due to a host of factors, including one of the highest gasoline taxes in the nation, my constituents pay some of the highest gas prices in the nation. In fact, just yesterday the American Automobile Association showed that gasoline is more expensive in my district than it is in Manhattan. In both places gas is at least 50 cents a gallon higher than it was at this time last year.

Already reports are showing that Wisconsin residents may soon be feeling even more pinched due to rising fuel costs. The Capital Times in Madison reported that freight truck drivers are feeling the weight of higher diesel prices, citing data from AAA Wisconsin that shows diesel averaging $4.08 a gallon, up more than 50 cents from just last month.

The story correctly notes that about 80 percent of the goods shipped in the U.S. use diesel powered trucks. The truck drivers are feeling the pinch, but it is being passed on to all of us. In fact, the high price of oil is one reason why my local investor owned utility, We Energies, is asking state regulators to approve a rate hike.

It is not surprising that gas and oil prices are going up. Worldwide demand is skyrocketing, too. Not only is there an increasing need for energy resources in this country, but countries like China and India have energy demands that far exceed their historical needs.

One thing we know for sure is that the worldwide demand for energy resources is going to keep growing in the future and that we need an energy policy that will allow us to meet those needs without slowing the economy.

Last May the Select Committee had a hearing on rising gas prices where we heard about the big impact that the oil and gas companies have on the economy. Everyone knows the impact that gasoline can have on goods in the market, but we also heard that these companies create a lot of good jobs and their expanded investment in market driven research and technology only serves to create more jobs.

The oil companies that we will hear from today are going to be called on to help meet the rising global energy demand. Naturally they are looking for new sources of traditional fossil fuels, and it is my hope they will continue to bring these new energy sources on line. Unfortunately, many of those sources are on unstable parts of the world with unsavory leadership, places like Nigeria and Venezuela.

But from their testimony today, it is clear that the oil companies are looking for new sources of energy like wind, solar, and biofuels. There is a growing market for these new technologies. These executives know what the future holds both from their own studies and from groups like the National Petroleum Council. They know that their companies will have to be able to draw on diverse sources of energy in order to meet the rising demand.

Now, I, too, believe that energy diversity must be a key part of U.S. energy strategy, and that includes traditional fossil fuels in addition to renewable energy, improved energy efficiency, and nuclear power. Any reasonable energy policy must recognize that we need affordable supplies of energy, and that oil and gas must continue to play a dominant supply role for the foreseeable future.

I look forward to today's testimony from our witnesses who are striving to meet the challenge of securing energy in an insecure world and yield back the balance of my time.

The CHAIRMAN. Okay. The gentleman's time has expired.

The Chair recognizes the gentleman from Oregon, Mr. Blumenauer.

Mr. BLUMENAUER. Thank you, Mr. Chairman.

I appreciate the opportunity to hear from the witnesses about their ideas about how to increase the use of renewable and alternative energy sources and reduce our dependence on oil.

You framed part of the question. People are, I think, understandably anxious about issues, the juxtaposition of record profits while paying more from the pump, and I look forward to people clarifying that part of the equation.

But it leads to a discussion about what subsidies, if any, oil companies actually need to continue to be successful and at what part of the energy business. We have seen the industry capable of making profit selling existing cost effective technology, but still we see billions of dollars in subsidies from the American taxpayer, one of which it never really was intended to get when we made the change in 2004 repealing an export subsidy that was in violation of the WTO rules. The oil and gas industry was explicitly not eligible for the repealed subsidy, yet through the magic of the legislative process found themselves included in the replacement benefit, a bonus to the industry that was already booming, and as you quoted President Bush, oil at $55 a barrel he said did not need incentives for oil and gas companies to explore.

I am interested in being able to explore with our witnesses at what point an industry becomes sufficiently mature that it no longer needs as much taxpayer help, and what parts of the businesses that are represented here today do need specific subsidies to be profitable.

In the written testimony that I have reviewed, you describe a robust renewable and alternative energy program that virtually all of the companies are involved with now and express support for renewing tax credits for the production of wind and solar power.

I personally believe that this is where we should be putting scarce taxpayer resources, not into existing technology which probably no longer needs our help, but in areas where the cost of production and the curve of cost effectiveness is not quite as clear.

And I look forward to being able to explore with our witnesses how we have passed this point and where we need to go in the future to maximize our entry into a renewable, sustainable future.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you.

The gentleman's time has expired. The Chair recognizes the gentleman from Arizona, Mr. Shadegg.

Mr. SHADEGG. Thank you, Mr. Chairman, and I assume that we are working under the rule that if I abbreviate my opening statement I get more time to ask questions?

The CHAIRMAN. I think it is an all or nothing.

Mr. SHADEGG. It is an all or nothing situation. Very well. Well, then it is an all.

Thank you very much, Mr. Chairman, for holding today's hearing. I think it is extremely important for us as Members of Congress, as well as for all Americans to understand the myriad of reasons for today's extremely high oil prices and the consequent high price of gasoline.

In that respect, this hearing is very timely considering that oil prices recently reached a $112 per barrel high just a few weeks ago. I am extremely interested in this issue as representing a western state where we travel great distances and our commutes are dramatically longer than those of my colleagues who represent states along the East Coast. These issues are extremely important to me.

And I also find that there is a sad lacking of basic economic understanding both here in the United States Congress and in the nation at large. There are many issues, I believe, which are contributing to the high price of oil and the consequent high price of gasoline.

I have in the past tried to encourage further construction of refining facilities without much luck. I believe we are relying on oil for many uses that would be better suited to other fuels.

I am concerned that if you look at both the issues of supply and demand, we face a myriad of problems. We face government imposed restrictions on supply. There are many, many places, I think, that all of us know here in America where we have known reserves of supply, but we are not allowed for various political reasons to go and look.

Just over a year ago this Congress looked at trying to get either oil production or natural gas production on the Outer Continental Shelf at distances far enough off the shore where it would be literally unknown to anybody on land, and yet we could not enact that legislation.

In the Air Mountain West where I live, we have thousands of acres of land that are locked up, and we walk away from that supply at a time when demand around the world is growing dramatically. China has moved quickly toward being a developed nation. It has an incredible demand for all commodities, including oil, and as that demand goes up, of course, that creates a greater demand around the world.

The result of this is, I believe, not surprising, and it is a spike in the cost of oil for Americans and a spike in the cost of gasoline for my constituents who are deeply concerned about the issue. As my colleague, Mr. Sensenbrenner, noted, we are forced regrettably to rely on nations that are not our friends to supply oil, and it is my understanding at least that U.S. oil companies control less than ten percent of the world's proven oil reserves, leaving American consumers often subject to oil prices determined largely by foreign countries and in some instances by foreign countries who are not our friends and who use that money to oppose us.

Obviously, we have a tremendous interest in exploring alternative forms of energy. I am keenly interested in that myself and would like to hear what you have to say about it. I, however, do not believe that funding alternative energies by taxing current forms of energy serves American consumers well.

And with that, I yield back the balance of my time.

The CHAIRMAN. The gentleman's time has expired.

The Chair recognizes the gentleman from Washington State, Mr. Inslee.

Mr. INSLEE. Thank you.

Just as I was walking in this room I had a fellow from Virginia, told him where I was headed into, and he said, "Congressman, I own stock in one of those companies, but give them hell anyway."

And I thought it was kind of indicative of what you know is the public sentiment out across the country, but I think that public sentiment is not because Americans do not understand the laws of supply and demand and we know that demand is going up with China and India and supply is somewhat limited. It is because of these two great abuses that they feel are going on that create this great anger besides just the price rise, and that is, first, they cannot understand when they're paying 328 or 344 out in my State of Washington at the pump why then you then reach into their pockets and take out another $18 billion on April 15th out of their tax bill. They cannot understand that.

And when they ask me to give you H., I think that is one of the reasons, because Americans believe and I think rightfully so that if you were going to give awards for taxpayer abuses, this would win the Heisman and the Oscar and the Nobel Prize, to reach into Americans' pockets at tax time to take this when these prices are going up like this.

And, secondly, Americans are concerned that even though we know, we know we have to wean ourselves off of oil and gas, that global warming demands this, even though Americans know that we are the most innovative people on the face of the earth, we are still seeing a very, very small as a percentage of your revenues investment in the clean energy technologies that Americans know that we can perfect to really create a clean energy revolution in this country.

So I hope that we will produce some thoughts about that. I will give you one saving grace. I know this to be a difficult hearing for you. I am not going to ask for your home phone numbers, and that could be the most effective regulatory system we have, but that is the one break you will get today.

Thank you.

The CHAIRMAN. The gentleman's time has expired.

The Chair recognizes the gentleman from Oregon, Mr. Walden.

Mr. WALDEN. Thank you very much, Mr. Chairman, and thank you for holding this hearing.

I want to welcome our witnesses, and we look forward to your testimony.

I share the concerns you have already heard from members of both sides of the aisle. Certainly in a district that spans 70,000 square miles, I can tell you I am hearing a lot from folks I represent, farmers and ranchers and others who commute extraordinarily long distances, about the price of fuel.

You know that. We hear it for diesel as well, especially in the farm community. The inputs into our agricultural products are a real problem.

What I would like to get to today is to find out how do we overcome this. Now, I am a big supporter of renewable energy and have been before it was even popular. Over the last month I bought my second hybrid vehicle. I now drive one in Oregon and one here in Washington, DC, and with all due respect, I have cut my payments to you by 66 percent with my new one in Oregon.

I want to know though how we do both. How do we meet the oil and gas needs of today in America while we develop the renewable energy sources, the biofuels, the alternatives that, frankly, are being developed in my district and elsewhere around the country? How do we get those going while we still meet this demand?

And we know part of the price spike we are paying on the world market is related to the devalued dollar. I mean, that is basic economics. You see it. We import so much. How do we get America more energy independent? How do we rely less on imports from foreign countries, many of whom, quite frankly, let's be honest, do not like us very well, Venezuela among them? So how do we develop our own resources?

What can we do to help in that effort rather than just throw rocks at you and your profits, which I think probably a lot of them have come from most of our districts? I want to know how we solve the problem.

That is what Americans want us to do here. We can gang up on you all, and certainly that will happen probably today, as you well anticipate, but I want to get beyond that and know how do we fix the problem in America so that we are energy independent, so we are secure in this country, so that we have the oil and gas we need as well as develop the renewables so that over the span we can grow out of an oil-based economy.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you.

The gentleman's time has expired. The Chair recognizes the gentleman from Connecticut, Mr. Larson.

Mr. LARSON. Thank you, Mr. Markey, and thank you for conducting this hearing, and thank you gentlemen for joining us today.

Let me start with saying that I believe that the laws of supply and demand, especially as relates to oil, are completely broken and malfunctioning. I would like to know your opinion on this. I would like to know whether you think that, in fact, speculators are driving up the cost, and paper is to account for a number of the reasons that let's say senior citizens have to turn over their entire Social Security check in order to pay for oil that is delivered to their homes in the Northeast.

And inasmuch as you receive 107 billion annually in taxpayer dollars, do you think that that is appropriate? I believe that the Independent Connecticut Petroleum Association is outraged, these rock-ribbed Republicans screaming that this whole situation has been nothing more than manipulation around greed, and they see it day in and day out with the customers that they are attempting to make deliveries to who are getting their homes foreclosed on, cannot afford prescription drugs, cannot afford to buy the food necessitated for their living, and yet are turning over their Social Security checks so that they can pay for their fuel.

That is the kind of problem that we are in, and lastly, with three percent of the reserves entirely in this nation, is it possible, do you believe that we can actually drill our way to energy independence?

The CHAIRMAN. The gentleman's time has expired. The Chair recognizes the gentlelady from Michigan, Mrs. Miller.

Mrs. MILLER. Thank you, Mr. Chairman.

This Committee was formed to study the issue of global climate change, how it impacts society, how it impacts our environment, and today we are going to hear from the leaders of companies that many in the environmental movement blame for many of the challenges that we face today. Of course, these are the big oil companies.

And in the difficult economy that our nation faces, this is the one industry that is thriving more than ever because of the incredibly high cost of oil. And everybody complains about the high cost, including probably every member of Congress as well, but I will say this at the outset. I think we should all take a very good look in the mirror as to some of the culprits about some of the high costs. We have done nothing as a Congress to advantage ourselves of our own domestic supply of energy resources in places like the ANWR or offshore reserves that would make us much less dependent on foreign oil.

We have not made it very much easier to site new refineries that could increase the supply of gasoline and reduce prices, and we have regulated ourselves to an extent that drives prices up.

But we have asked many in industry to make sacrifices and new investments, and many of them have actually responded. Our domestic auto manufacturers have borne the brunt, quite frankly, of this effort, and they are responding. They have heard the call. They have shouldered the mandates, and they are responding.

Many other American companies and industries are also responding as well. But despite all of this effort, our economy is still overly reliant on oil. The big oil companies continue to reap huge benefits.

And I say this. I believe this very strongly, that before we are members of Congress or before we are oil executives or what have you, before we are anything else, we are all Americans. And every American has a responsibility to help reduce our dependence on foreign energy sources and also to conserve energy.

And I hope on this Committee that we all are very familiar with the record profits being reaped by the oil industry, which in fact stand in very sharp contrast to the financial situations of many other industries who have been asked to make sacrifices to help us solve our energy problems. I hope that your companies, who are in a position really to be a major player in a brighter economic environmental future, that you do the right thing with these profits.

Simply having these profits fatten the checkbooks of a few instead of investing for the good of us all is down the wrong path. You are in the position to invest in new, cleaner technologies that will not only change your industry, but could change the entire world if you have the courage and the foresight to do so.

And if you do not have that courage, if you refuse to change with America, then I believe you are going to see a backlash from your customers, the American people who are sick and tired of paying huge prices at the pump only to see your companies swimming in their money, and you are going to see a backlash from other industries that are being decimated by high fuel prices.

And because of that, you will also see a backlash from this Congress that could go further than just the elimination of tax breaks that you currently enjoy when we see that your companies have made combined profits of over $123 billion last year alone.

And I also think you will see a backlash from your shareholders who will bear the brunt of the pain if you do not evolve to other energy technologies that will eventually replace oil as a primary energy source. So I hope that what we will hear today is not just a defense of record profits or a casting of blame on others for high prices or defensive tax breaks without the needs of good corporate citizenship or sticking your head in the sand and denying the effort to bring about alternatives to oil, and I look forward to all of your testimony.

Thank you, Mr. Chairman.

The CHAIRMAN. The gentlelady's time has expired.

[The prepared statement of Mrs. Miller follows:]

Congresswoman Candice Miller

This committee was formed to study the issue of global climate change.

How it impacts society and our environment.

What is causing it.

What can be done to change it if indeed it is caused by man.

We have heard from leaders from environmental organizations, governments, private citizens and leaders of companies advancing new technologies.

And today we will hear from the leaders of companies that many in the environmental movement blame for many of the challenges we face today.

They are also presently reviled by the American people who are being squeezed by the skyrocketing cost of gasoline.

These are the leaders of the big oil companies.

In the difficult economy our nation faces this is one industry that is thriving more than ever because of the incredibly high cost of oil.

Everyone complains about that high cost including nearly every member of this Congress.

But if we want to see some of the culprits for those high costs all we have to do is look in the mirror.

We have done nothing to advantage ourselves of our own domestic supply of energy resources in places like ANWR or off shore reserves that would make us less dependent on foreign sources of energy.

We have done nothing to make it easier to site new refineries that could increase the supply of gasoline and reduce prices.

We have regulated ourselves to an extent that drives prices up.

But we have asked many in industry to make sacrifices and new investments to limit our usage of energy and many in this economy have responded.

Our domestic auto manufacturers have borne the brunt of this effort.

They are being told to produce vehicles that are more fuel efficient while also trying to build vehicles that consumers demand.

And they are responding.

All of the Big Three are ramping up the production of advanced hybrid vehicles.

They are producing cars that can run on E-85 ethanol that outstrip our ability to produce the fuel.

They are planning to soon introduce plug-in hybrid vehicles run on advanced battery technology that could revolutionize the industry.

They are researching vehicles that can run on hydrogen and many other alternative fuels.

They are building plants like the new Ford Rouge Plant which is one of the greenest in all of industry.

They have heard the call, they have shouldered the mandates and they are responding.

Many other American companies and industries are responding also with money being poured into research, development and deployment of new energy technologies.

But despite all of this effort our economy is still overly reliant on oil.

And the big oil companies continue to reap those benefits.

And America is demanding change to make us less reliant on this expensive energy source that is blamed for so many of our problems.

And I believe this strongly, before we are members of Congress or before we are oil executives, or before we are anything else, we are all Americans.

And every American has a responsibility to help reduce our dependence on foreign energy sources and conserve energy to benefit all of us.

Whether it is investing in new technology to run a cleaner factory, our producing higher mileage cars, or investing in wind turbines to supply our electricity, or turning off the light when you leave a room – we can all do something to help solve the problem.

Now we on this committee have heard from many who hope to be a part of the solution and that is what I hope we hear from all of you today.

We all know about the record profits being reaped by the oil industry which stand in sharp contrast to the financial situations of other companies who have been asked to make sacrifices to solve our energy problems.

Your companies are in the position to be major players in a brighter economic and environmental future if you do the right thing with those profits.

Simply having those profits fatten the checkbooks of a few instead of investing for the good of us all is the wrong path.

You are in the position to advance new cleaner technologies that will not only change your industry but could change the entire world if you have the courage and foresight to do so.

If you do not have that courage, if you refuse to change with America then I believe you will see a backlash from your customers, the American people, who are sick and tired of paying huge prices at the pump only to see your companies swimming in their money.

You will see a backlash from other industries that are being decimated by high fuel prices.

And because of that you will see a backlash from this Congress that could go further than just the elimination of tax breaks you currently enjoy which are becoming increasingly difficult to justify when your companies are making combined profits of over $123 billion last year alone.

I also believe you will see a backlash from your shareholders who will bear the brunt of pain if you do not evolve to other energy technologies that will eventually replace oil as a primary energy source.

So you need to look beyond the next quarterly balance sheet. You need to make real investments in technologies and not just lip service to alternative energy.

Just as the maker of the horse carriage would have been wise to transition to building bodies for automobiles or telegraph operators would have been wise to transition to become telephone companies your organizations would be wise use your record profits to be the leaders in providing the next energy sources.

I hope what we will hear today is not just a defense of record profits, or a casting of blame on others for high prices, or defense of tax breaks without the need for good corporate citizenship, or sticking your head in the sand denying the effort to bring about alternatives to oil.

All of that would be counter-productive and waste of all of our time.

I often hear a commercial on the radio back home for Marathon Oil Company that ends with the tag line – An American Company serving America.

You are all American companies. How are you serving America?

The Chair recognizes the gentleman from Missouri, Mr. Cleaver.

Mr. CLEAVER. Thank you, Mr. Chairman.

Mr. Chairman and Ranking Member Sensenbrenner, thank you for this meeting.

I think all of you are already hearing what is going on at home. We have been on a break. It has actually been a work break for most of us, and one of the things that we hear over and over again is what are you guys going to do about the high price of gasoline, and I spoke with a woman about a week ago who earns $18,000 a year and cannot afford to fill up her tank to get to work. Kansas City, Missouri does not have mass transit. We only have buses, and so she is about to lose her job because she cannot afford to get to it. And so she is losing all the way around.

And with the skyrocketing price of a barrel of oil and people paying more than $3 a gallon in Missouri, the anger level is rising significantly, and my concern is that we not have a dialogue today about, you know, whose fault it is. I think I came here prepared to hear everyone say, “It is not our fault,” but I think it is the fault of people in this room, and I think something can be done.

The perception is terrible. I mean people talk about the perception of Congress, and you know, our approval ratings. Your approval ratings are lower than ours, and that means you are down low, and I think you probably have the lowest approval ratings in the nation.

So I am hoping that before this session is over you can raise your approval ratings by giving some real answers.

Thank you, Mr. Chairman. I yield back the balance of my time.

The CHAIRMAN. Great. The gentleman’s time has expired.

[The prepared statement of Mr. Cleaver follows:]

U.S. Representative Emanuel Cleaver, II
5th District, Missouri
Statement for the Record
House Select Committee on Energy Independence and Global Warming Hearing
"Drilling for Answers: Oil Company Profits, Runaway Prices and Pursuit of Alternatives"
Tuesday, April 1, 2008

Chairman Markey, Ranking Member Sensenbrenner, other Members of the Select Committee, good morning. I would like to welcome our distinguished panel of witnesses to the hearing today.

As the price of oil skyrockets past $105 per barrel, and Americans are paying well over $3 for a gallon of gas, we cannot ignore our country is in an energy crisis. The answer to this problem is comprehensive, and must include energy that is renewable, if we are to become truly energy independent. Renewable alternatives to oil like wind, solar, hydrogen, and biofuels have the ability to aid in making our country more energy independent. My mobile office unit in Kansas City, Missouri runs on grease from local restaurants. This may not be realistic for every vehicle in the country, but it's certainly a start.

While the prices of oil and gasoline increase, oil companies are reporting record profits on a seemingly annual basis. I firmly believe the success of business, especially that of American companies, is important to our economy, particularly at this difficult time. However, the disparity between the profits of companies producing oil and gas and the increasing prices at the pump are inexplicable. I hope that the representatives visiting us today will be able to clarify these concerns, and also to give us an indication of what the future of energy is for our country.

I thank all of our witnesses for their insight, and I appreciate them taking the time to visit with our committee this morning.

Thank you.

The Chair recognizes the gentleman from Oklahoma, Mr. Sullivan.

Mr. SULLIVAN. Thank you, Mr. Chairman.

And I am really glad that you are here today. I appreciate you taking the time to come here to discuss climate change and energy independence. We want to see our country move toward energy independence, but we want to do it in a way that does not sacrifice jobs in America.

Congressman Cleaver, I, too, was on a break recently, and I heard people talking about things, but one of the biggest things I heard about when I was home is that people are concerned about their food prices going up because of ethanol. They think that they are using all of the corn in this country, that people are going to the grocery store. A loaf of bread costs a lot of money right now, and that is one of the ways we tried to address it, and I think that that is a big problem. I heard that more than people talking about gas prices, actually, talking about a loaf of bread. You know, that is a big problem.

I want to thank again all of you for being here. Also, Mr. Lowe from ConocoPhillips, I appreciate you being here. The ConocoPhillips is in my district. It is a big company, and they employ a lot of people.

One of the things, too, I get tired of hearing about, is everybody, all politicians, you cannot hear a political speech almost daily without someone saying big oil, big oil. I guess every politician has to have a tangible devil to fight, but I get tired of hearing that.

I do want to hear about what you guys have to say about what is going on, and I appreciate you, again, for being here and taking the time to discuss this very important issue.

Thank you.

The CHAIRMAN. Great. The gentleman's time has expired. The Chair recognizes the gentleman from New York State, Mr. Hall.

Mr. HALL. Thank you, Mr. Chairman, and thanks to all of our witnesses for being here.

As we all know, the price of oil has been rising at a dizzying pace for the last several years, recently shattering the all time high and hovering above $100 per barrel. The numbers and impacts on both sides of the equation are staggering. Today the average price of regular unleaded gas in the United States is $3.29, up 60 cents from just last year.

In New York the situation is even worse with the cost at over $3.40, and my constituents talk about the rockets and feathers syndrome where the price seems to go up like a rocket and when it comes down, it kind of comes down like a feather, not quite so fast.

President Bush may not have known about the concern that gas was going to break the $4 mark, but with prices already well above $3 before the summer, most Americans do not need to be reminded. They already see the impact on their bottom line every day.

On the other side of the coin, we have the companies you gentlemen represent before us today. Since 2002, the combined profits of the five largest oil companies have quadrupled. Last year they made over $123 billion, shattering dollar records of their own. During this hearing there will be a great deal of discussion trying to explain away these profits saying we need to reinvest. We are a big company. Per dollar we do not make that much more than anybody else.

But the bottom line is that these are the biggest profits in corporate history and that if the oil companies are not making a killing off of these prices, who is? Certainly not the average family that pays more than it can afford to drive to school or for Dad to drive to work. Something is wrong, and we need to fix it. We need to stabilize our economy, give working families a break, and take action to mitigate climate change.

On this last front I am encouraged that some of the witnesses have expressed support for a carbon reduction plan and support for and indeed investment in renewable and alternative energy sources. I hope we will be hearing today about how you can follow through and work with Congress to shape a policy that will take on climate change and also save our constituents from the squeeze they are current caught in the middle of.

Thank you very much, Mr. Chairman. I yield back.

The CHAIRMAN. I thank the gentleman from New York. His time has expired.

And the Chair recognizes the gentlelady from Tennessee, Ms. Blackburn.

Ms. BLACKBURN. Thank you, Mr. Chairman.

I want to thank each of you for coming before us today, and my hope is that our Committee will have a reasoned discussion with you and that we will benefit from your experience and from your expertise and insight.

I also hope that we are not going to sit here and try to place blame for what may be causing this. We have a problem to solve, and the problem is the high cost at the pump.

Now, since January '07, we have passed new energy taxes, new mandates, new burdens, new regulatory burdens on energy companies trying to impose and move toward renewable energy, and it would appear that we are not getting the results that we want from some of those actions because we have seen gas go from $2.26 a gallon up to $3.29, where it is today.

We have seen over a 44 percent increase on the family budget. For every one dollar that gallon of gas goes up, that costs the family, an average family, about $600 directly out of their pocketbook.

You all know the prices of crude, and today they are hovering right around $100. So there are some that would like to place blame on all of you and would place extra taxes on you, but I have got a question that I would like to pose, and it is this. If we take those actions, if we put more taxes on you and more regulation and more compliance, would it put this nation at risk for even more dependence on foreign, unfriendly sources of oil?

What about a carbon tax or a cap and trade system? What is that going to do to the American public? We all know that America has the capacity to become energy independent and help lower energy cost. Do we have the national will to do this?

We all know we have vast coal, oil, and gas resources lying on or within our land and off the coast, and these can be developed, and our allies to the north are developing access to one of the world's largest sources of natural energy resources in the Canadian shale oil.

Let's not be shortsighted. Let's put the family first. Let's not let fear grip and manipulate our policies. We have a problem to solve. We need to work together on this.

I yield the balance of my time.

The CHAIRMAN. The gentlelady's time has expired.

The Chair recognizes the gentleman from California, Mr. McNerney.

Mr. MCNERNEY. Thank you, Mr. Chairman.

I also want to thank the witnesses for joining us today on this critical topic, particularly to thank Mr. Robertson for coming here to represent Chevron, which is located in my congressional district in San Ramon, California.

Well, it is obvious that businesses must show profits and be accountable to their shareholders. We seem to have a perfect storm of factors that have led us to the topic we are considering today, record high oil prices, record high profits for oil companies and clear evidence that the Earth's atmosphere is warming.

But I am hopeful today's hearing will help us better understand exactly what the industry's perspective on these issues is and as someone with a background in renewable energy, I do not believe that the oil and natural gas companies should be at odds with the renewable industry. The two should work in concert, and that makes perfectly good business sense.

While petroleum resources are limited, renewable resources have the potential to address our nation's long-term energy needs. So by investing in renewable energy, oil and gas companies can look toward the future and can pioneer initiatives with your resources that will give us significant long-term dividends.

We know that progress is being made by companies such as Chevron, which is investing in energy efficiency, geothermal, hydrogen, and biofuels. This approach should be more widely adopted, in my opinion, and embraced across the board. The companies' representatives today have at their disposal the resources necessary to move forward securing our nation's long-term energy future, and what we need now is a commitment and vision to make that happen.

Again, I look forward to your testimony and yield back to the Chair.

The CHAIRMAN. The gentleman's time has expired.

The Chair recognizes the gentlelady from California, Ms. Solis.

Ms. SOLIS. Thank you, Mr. Chairman, and thank you for having this important hearing.

And also welcome to our witnesses. While I do not pretend to lay blame on you specifically, I do lay blame on the fact that our constituents certainly need to have some questions answered.

And how is it that I can explain when I go back home, coming back from our recess, that the price of a gallon of gasoline in my district, East Los Angeles, San Gabriel Valley, working class blue collar, is upwards of $3.69 a gallon. For diesel it is over $4.00.

And the questions that I get from people, especially our truckers because we have a very busy port in Los Angeles and much of that transaction occurs through my district, so people are going broke; they are going bankrupt. But they want to know why is it that these folks are making such a heavy profit, a large profit over a small span of time, and that money then, and also those profits, cannot be redirected into renewable energy and fuels and hopefully increase the ability to create new green collar jobs.

Every time that we keep away from the message of creating and investing in the United States with renewable energy, I think we are losing upwards of 100,000 jobs. At least that is what I am being told.

So I am just asking you to please step up to the plate. Help us find those answers to our questions. Help us look for other alternatives, and the suggestions that I do not want to hear are that we are going to keep drilling where we already know, folks in our district particularly, California, do not want to allow for more drilling along our coast and opening up old refineries like in the City of Wittier.

Nixon Country it used to be known as, where we have some oil fields owned by, I think, Chevron.

So I would just leave you with that and ask you to please keep in mind the constituents that we represent, and yield back the balance of my time.

[The prepared statement of Ms. Solis follows:]

Opening Statement – Congresswoman Hilda L. Solis
Big Five Oil Company Hearing
April 1, 2008

Mr. Chairman, thank you for holding today's hearing.

Our nation's dependency on oil is hurting our consumers, our businesses, our economy, and our security.

The nationwide average price of a gallon of gas has more than doubled since 2001 and in the last year it has increased by more than 20%!

It is $3.65 in parts of my district.

Small businesses are hurting too.

In 2006, when prices were considerably less, more than 86% of small businesses reported the cost of fuel had a negative effect on their revenue.

The increasing cost of fuel has restrained both consumer spending and business investment.

The cost of gasoline is made even worse by the overall economy.

Payrolls fell by 63,000 in February and this Friday the Labor Department is expected to announce that they fell by another 50,000 in March.

More than 650 families are facing foreclosure in the communities I represent and unemployment is nearly 7%, well above the national average of nearly 5%.

The dollar near its all-time low against the Euro yesterday and may weaken further as the Federal Reserve moves to cut interest rates again later this year.

Frankly, it is very difficult for my constituents to understand how it is that they are paying 123% more for gasoline at the same time your profits increased by 310%!

You are here today because we must work together to rein in our nation's dependency on oil and stabilize our economy.

I believe that we can do both.

But you must stop objecting to changes in the tax code which will even the playing field, changes which were passed by the U.S. House just one month ago.

You must join us in committing to a strategy of diversifying our energy sources through significant, long term investments in clean, secure energy sources.

If we can do this together, I believe that we can help stabilize and even grow the economy while improving national security.

I yield back the balance of my time.

The CHAIRMAN. The gentlelady's time has expired, and the Chair recognizes the gentlelady from South Dakota, Ms. Herseth Sandlin.

Ms. HERSETH SANDLIN. Thank you, Mr. Chairman, and thank you to our witnesses for being here today at this hearing.

Yesterday, as we know, light sweet crude for May delivery was trading above $101 per barrel on the New York Mercantile Exchange, and these developments continue to be shocking and financially burdensome for families and businesses across the country, especially rural America like South Dakota, the state that I represent here in the Congress, since people drive such long distances daily to get to work, to get their kids to school, to transport goods for their small businesses.

The average price for a barrel of oil in January of '02, about six years ago, was less than $20 a barrel. So even if we discount all of the other problems, whether they are geopolitical, environmental, supply, that flow from our addiction to oil, its price volatility alone seems to me dictates that we must more aggressively move to diversify our energy sources.

Now, I strongly believe one solution to this oil addiction is an increased use of domesticly produced biofuels, such as ethanol, which have the potential to meet a significant portion of our nation's energy needs over the coming decades if we put the proper policies in place. This includes the robust and aggressive renewable fuel standard passed last December that drives the development and large scale production of cellulosic ethanol in the decades to come.

And I just would have to note for my colleagues on the Committee, I know Mr. Sullivan mentioned the concern of his constituents about food prices. It has been shown that it has been energy prices associated with the processing and the transport of food far more than the cost of the commodities, such as corn and wheat, that are substantially driving up costs of food, and perhaps what we should evaluate, Mr. Chairman, and that is some of what we have been trying to do and some of what we have proposed in energy policies that have passed the House as it relates to reevaluating some of the policies we put in place years ago, including in 2005, but before that.

Because for those of you who do not represent agriculture, our farm policies, most of them, kick in when prices are low. So we save taxpayers money when we are not paying loan deficiency payments or counter cyclical payments, when the price of corn is where it has been, over $4 a bushel, the price of wheat, the price of soybeans with what they have been.

And so we need to look at doing the same thing when it looks like other commodities' prices are so volatile and going up, to reevaluate how we spend taxpayer dollars when prices are high and when they are low, and we will look forward to getting your thoughts on that, as well as your thoughts on biofuels distribution and production across the country.

Thank you, Mr. Chairman.

The CHAIRMAN. The gentlelady's time has expired and all time for opening statements from the Members has been completed. So now we will turn to our panel, and we will give each one of them an opportunity to make an opening statement before this Committee.

Our first witness today is Mr. Stephen Simon, Senior Vice President for ExxonMobil. Mr. Simon has over 40 years of experience in the oil industry, 35 of them spent with Exxon. He has served in his current role as Senior Vice President since 2004.

We welcome you, Mr. Simon. Whenever you are ready, please begin.

STATEMENT OF STEPHEN SIMON, SENIOR VICE PRESIDENT, EXXON MOBIL CORP.; ACCOMPANIED BY JOHN HOFMEISTER, PRESIDENT, SHELL OIL COMPANY; ROBERT ROBERTSON, VICE CHAIRMAN, CHEVRON; JOHN LOWE, EXECUTIVE VICE PRESIDENT, CONOCOPHILLIPS; AND ROBERT A. MALONE, CHAIRMAN AND PRESIDENT, BP AMERICA, INC.

STATEMENT OF STEPHEN SIMON

Mr. SIMON. Thank you, Chairman Markey, Ranking Member Sensenbrenner, and members of the Committee.

The world's economy runs on energy. Americans depend on it every day to fuel their cars, heat their homes, and power their businesses. Because energy is so important, all of us have a responsibility to engage in an open, honest, informed debate about our energy future that is grounded in reality and intent on finding viable solutions.

In that spirit, I would like to make three points during my allotted time. First, our earnings, although high in absolute terms, need to be viewed in the context of the scale and cyclical long-term nature of our industry, as well as the huge investment requirements.

Second, stable tax and regulatory policies are essential to encouraging needed investments. Imposing punitive taxes on American energy companies which are already paying record taxes will discourage the sustained investments needed to continue safeguarding U.S. energy security.

Third, all reliable and economic forms of energy are needed to meet growing needs, but the pursuit of alternative fuels must not detract from the development of oil and gas.

Allow me to elaborate on each point in turn.

Because of the massive scale of our industry, our profitability in absolute terms is large, particularly in the current up cycle, but in 2007, the oil and gas industry earned on average about 8.3 cents per dollar of sales, near the Dow Jones Industrial Average of major industries of 7.8 cents per dollar of sales.

Because ours is a commodity business, earnings rise and fall in cycles. We are currently in an up cycle, strongly influencing our current profitability, but we have seen up and down cycles before. In 1980 crude oil prices reached record levels, approaching the equivalent of over $100 a barrel in today's dollars, and many were predicting that oil prices would soar to over $250 a barrel in today's dollars, but those predictions were wrong.

By the mid-1980s, prices had fallen dramatically and the industry was in dire straits. Ours is a long-term business with energy projects requiring enormous investments spanning decades that must carry through both the up and down cycles.

Over the last 25 years, we have invested $355 billion, which is more than we earn. In the last five years alone, we have invested almost $89 billion, including about $25 billion in North America. Over the next five years, Exxon Mobil plans to invest at least $125 billion.

We depend on high earnings during the up cycle to sustain this level of investment over the long term, including the down cycles.

Regarding taxes, currently the energy industry pays record levels. While our worldwide profits have grown, our worldwide income taxes have grown even more. From 2003 to 2007, our earnings grew by 89 percent, but our income taxes grew by 170 percent. Over the last five years, Exxon Mobil's U.S. total tax bill exceeded our U.S. earnings by $19 billion.

A recent survey by Tax Notes of 80 leading U.S. companies revealed that these companies had an average income tax rate of 30 percent. Exxon Mobil's effective income tax rate in 2007 was 44 percent.

To discriminate against American energy companies, as the proposed changes to Section 199 in the foreign tax credit due would not only add to these taxes, but also impact investment in future energy supplies by redirecting needed capital and creating competitive disadvantages for American energy companies competing overseas.

Taxes should be fair, stable, and pro competitive, principles these proposals violate.

Finally, regarding alternatives, the International Energy Agency forecast that oil and gas will continue to meet about 54 percent of global energy demand in 2030. Alternative fuels also play an important role, but the IEA forecast that renewable energy sources, such as biofuels, wind, solar and geothermal combined, will account for only about two percent of global energy supply in 2030, again, an indicator of the scale required.

These findings are closely aligned with our own Energy Outlook of 2007, which I respectfully submit into the records of this proceeding for the Committee's consideration.

The market is the most effective means of determining the future energy mix in a way that maximizes supply and minimizes cost. Government mandates and subsidies distort market forces and impeded technological innovation. Raising taxes on oil and gas production to subsidize alternatives will likely lead to less overall energy production, not more.

And as many independent observers are now noting, such mandates can have unintended consequences, continuing to provide Americans with the energy they need reliably and responsibly is a challenge Exxon Mobil employees are determined to meet. Government can help by creating a level playing field and promoting fair, stable, pro competitive regulatory and tax policies.

It is this kind of leadership that is needed to meet our nation's energy challenges.

Thank you.

[The statement of Mr. Simon follows:]

J. S. Simon
Exxon Mobil Corporation
Hearing of the U.S. House Select Committee on
Energy Independence and Global Warming
April 1, 2008

Thank you, Chairman Markey, Ranking Member Sensenbrenner, and members of the Committee.

The world's economy runs on energy. Americans depend on it every day to fuel their cars, heat their homes, and power their businesses.

Because energy is so important, all of us have a responsibility to engage in an open, honest, informed debate about our energy future that is grounded in reality and intent on finding viable solutions.

In that spirit, I would like to make three points during my allotted time.

First, our earnings, although high in absolute terms, need to be viewed in the context of the scale and cyclical, long-term nature of our industry, as well as the huge investment requirements.

Second, stable tax and regulatory policies are essential to encouraging needed investments. Imposing punitive taxes on American energy companies, which already pay record taxes, will discourage the sustained investments needed to continue safeguarding U.S. energy security.

Third, all reliable and economic forms of energy are needed to meet growing needs – but the pursuit of alternative fuels must not detract from the development of oil and gas.

Allow me to elaborate on each point in turn.

Because of the massive scale of our industry, our profitability in absolute terms is large, particularly in the current up cycle. But in 2007, the oil and gas industry earned, on average, about 8.3 cents per dollar of sales – near the Dow Jones Industrial Average for major industries of 7.8 cents per dollar of sales.

Because ours is a commodity business, earnings rise and fall in cycles. We are currently in an up cycle, strongly influencing our current profitability.

But we've seen up and down cycles before. In 1980, crude oil prices reached record levels - approaching the equivalent of over $100 a barrel in today's dollars and many were predicting that oil prices would soar to over $250 a barrel in today's dollars. But those predictions were wrong - by the mid-1980s prices had fallen dramatically and the industry was in dire straits.

Ours is a long-term business, with energy projects requiring enormous investments spanning decades that must carry through both up and down cycles.

Over the last 25 years, we have invested $355 billion – which is more than we earned. In the last five years alone, we have invested almost $89 billion, including about $25 billion in North America (over $17 billion in the U.S. alone).

Over the next five years, ExxonMobil plans to invest at least $125 billion. We depend on high earnings during the up cycle to sustain this level of investment over the long-term, including the down cycles.

Regarding taxes, currently the energy industry pays record levels. While our worldwide profits have grown, our worldwide income taxes have grown even more. From 2003 to 2007, our earnings grew by 89 percent, but our *income* taxes grew by 170 percent. Over the last five years, ExxonMobil's U.S. total tax bill exceeded our U.S. earnings by $19 billion.

A recent survey by Tax Notes of 80 leading U.S. companies revealed that these companies had an average income tax rate of 30 percent. ExxonMobil's effective income tax rate in 2007 was 44 percent.

To discriminate against American energy companies – as the proposed changes to Section 199 and the Foreign Tax Credit do – would not only add to these taxes, but also impact investment in future energy supplies by redirecting needed capital and creating competitive disadvantages for American energy companies competing overseas. Taxes should be fair, stable, and pro-competitive – principles these proposals violate.

Finally, regarding alternatives, the International Energy Agency forecasts that oil and gas will continue to meet about 54 percent of global energy demand in 2030. Alternative fuels also play an important role, but the IEA forecasts that renewable energy sources such as biofuels, wind, solar and geothermal will account for only about two percent of global energy supply in 2030 - again, an indicator of the scale required.

The market is the most effective means of determining the future energy mix in a way that maximizes supply and minimizes cost.

Government mandates and subsidies distort market forces and impede technological innovation. Raising taxes on oil and gas production to subsidize alternatives will likely lead to less overall energy production, not more. And as many independent observers are now noting, such mandates can have unintended consequences.

Continuing to provide Americans with the energy they need – reliably and responsibly – is a challenge ExxonMobil employees are determined to meet.

Government can help by creating a level playing field, and promoting fair, stable, and pro-competitive tax policy.

It is this kind of leadership that is needed to meet our nation's energy challenges.

Thank you.

The CHAIRMAN. Thank you, Mr. Simon.

Our next witness is Mr. John Hofmeister. He is the President of the Shell Oil Company and has led that company since March of 2005.

We welcome you, Mr. Hofmeister, and if you could move in a little bit closer to the microphone, I think it would help everyone.

STATEMENT OF JOHN HOFMEISTER

Mr. HOFMEISTER. Chairman Markey, Ranking Member Sensenbrenner, members of the Committee, I welcome the opportunity to be here today.

If there is no objection, I will summarize the statement I have submitted for the record.

This hearing comes at the end of Shell's 18-month national dialogue on energy security. We traveled to 50 cities engaging more than 15,000 Americans in a dialogue on energy security. We heard what you are hearing. Americans are worried about the rising cost of energy.

Mr. Chairman, I believe you have said that the nation's energy challenge requires a commitment on the scale of the Manhattan Project during World War II or the Space Program of the 1960s. I agree.

The price of a barrel of light sweet crude has gone up 300 percent in four years. This increase is due to a combination of factors which are for the most part not controlled or much influenced by the actions of oil companies, for example, growth in global demand for oil, geopolitical events affecting international supply, developments in the financial market contributing to the rise in prices, skyrocketing cost of materials, labor, and engineering services, a shortage of capacity in energy services and materials, more difficult access to oil and gas resources around the world.

Available energy resources are found in difficult or hostile areas, and closer to home, U.S. energy resources are unavailable.

Today I will talk about three aspects of the energy challenge: first, what is the energy supply-demand outlook; second, what is Shell doing to meet the energy challenge; and, third, what policy makers can do.

First, the energy supply-demand outlook is sobering. Demand is increasing unrelentingly. Although oil and natural gas will be used to meet more than half of our energy needs for decades, U.S. oil and gas production has fallen steadily for the last 35 years. Why? Because government policies place domestic oil and gas resources off limits. The U.S. government restricts supply to U.S. consumers.

The result, we import more oil to meet our growing demand. In 2006, we imported 3.7 billion barrels of oil, more than seven times the amount imported in 1970. This brings me to my second point, what Shell is doing to meet the energy challenge.

We are making significant capital investment to produce more energy and more kinds of energy to meet global demand. Today we have doubled the number of new projects under construction that we had in 2004. Last year we spent some 25 billion on capital investment worldwide to develop energy projects.

This year Shell will spend between $28 and $29 billion, the largest capital expenditure program in the oil and gas energy.

Wind, we are involved in 11 wind projects across Europe and the United States where we have wind farms in six states with more under development.

Solar, Shell is an international developer of thin film solar technology to generate electricity from the sun's energy.

Biofuels, Shell is the world's largest blender of biofuels by volume and one of the world's largest distributors of transport biofuels. Shell is a leader in the development of advanced biofuels, such as cellulosic ethanol.

Hydrogen, Shell is a leader in developing transportation solutions with hydrogen. We operate the nation's first integrated gasoline hydrogen station nearby here at our Shell station on Benning Road. We also have proprietary gasification technology to convert coal and biomass into cleaner fuel. We lead in gas to liquids technology to produce cleaner transportation fuels. We hold a leadership position in the production of liquefied natural gas, here in the U.S., including at two existing LNG terminals.

But Shell continues to be an industry leader in the deep water Gulf of Mexico. Note that the costs of deep water exploration and production are immense and rising. Last year, for example, the average daily cost for a deep water exploration well in the Gulf of Mexico per day was $759,000.

Shell has a world class manufacturing organization to better meet customer demand of finished products. In the U.S. our joint venture at Motiva is spending around $7 billion to double the capacity of its refinery at Port Arthur, Texas. When finished, it will be one of the largest refineries in the U.S. and the world.

In oil sands and oil shale, Shell is investing in the technology and infrastructure to develop vast oil sands in Canada and oil shale in the United States.

To my third point, what can policy makers do to meet the energy challenge? First, the oil and gas development can occur in an environmentally responsible way. In 2006, Congress opened new areas in the Gulf of Mexico to exploration and development. More such access is warranted so that U.S. consumers can have access to U.S. natural resources.

Congress also provided energy producing states and local coastal communities with a revenue stream to help ensure economic and environmental stability. Such revenue sharing should be made available to all areas adjacent to offshore development.

Second, we need all forms of energy, plus conservation and energy efficiency. I commend Congress for including stronger CAFE provisions and other conservation measures in the 2007 energy bill. Congress should continue to encourage conservation.

Third, Shell supports reducing greenhouse gases through a cap and trade program coupled with sector approaches. We must work now to address CO_2 emissions as we make the transition from fossil fuels to new energy sources.

Thank you, Mr. Chairman. I'll be happy to answer questions.

[The statement of Mr. Hofmeister follows:]

Statement

of

John Hofmeister
President, Shell Oil Company

Before the

U.S. House of Representatives

Select Committee on Energy Independence
and
Global Warming

Tuesday, April 1, 2008

Drilling for Answers on Oil and Gas Prices, Profits, and Alternatives

Chairman Markey, Ranking Member Sensenbrenner and members of the Committee, I am John Hofmeister, President of Shell Oil Company.

Shell Oil Company is an affiliate of the Shell Group, a global group of energy and petrochemical companies, employing approximately 104,000 people and operating in more than 110 countries and territories. Shell Oil Company, including its consolidated companies and its share in equity companies, is one of America's leading oil and natural gas producers, natural gas marketers, gasoline marketers and petrochemical manufacturers. Shell, a leading oil and gas producer in the deepwater Gulf of Mexico, is a recognized pioneer in oil and gas exploration and production technology.

I welcome the opportunity to testify today. It is, in fact, very timely because it comes at the end of an 18-month Shell journey called "A National Dialogue on Energy Security." We traveled to 50 cities and visited with more than 15,000 Americans to engage in meaningful dialogue on energy security.

I heard what you are hearing.

Americans are very worried about the rising price of energy – the cost to fill their cars, as well as the cost to heat, cool and light their homes and businesses. These cost increases are hitting consumers hard, particularly the poor and those on fixed incomes.

Let's look at historical data on the price of a barrel of crude and the average price of regular gasoline. Since April 2004, the price of a barrel of U.S. light sweet crude has gone up by $70, which is a 300 percent increase. In this same period, the average U.S. nationwide price of regular gasoline at the pump went up 72 percent. Looking just at the last 12 months, the price of a barrel has increased $40, or more than 60 percent. The price of regular gasoline has gone up 8 percent.

There is no single reason or simple explanation for the recent run-up in crude oil prices. Rather, a combination of circumstances, some short-term and some long-term in nature, is playing a role.

Let me highlight some of these factors.

- The rate of growth in global demand for oil has accelerated in recent years. This is largely the result of rapid economic growth and industrialization in countries like China and India and also sustained subsidies on oil products in oil exporting countries.
- Geopolitical events, such as the disturbances in the Niger Delta, have reduced supplies available to the international market.
- The cost of materials, labor and engineering services has skyrocketed. This in turn drives up the cost of new energy projects and the cost of developing new energy supplies.
- There is a shortage of capacity in energy services and materials. This shortage is in some instances leading to project delays and lengthening the time it takes for new projects and new supplies to come on line to meet increased demand.
- Access to oil and gas resources is becoming more difficult around the world. This, coupled with more stringent fiscal conditions governing investment in several major oil and gas-producing countries, adversely affects the economics of new energy projects. It may lead to reductions in or delays of new investment in oil and gas supply capacity.
- The oil and gas resources that are available for development are increasingly found in extremely difficult or hostile areas – areas that are more technically challenging, more remote from markets, require more infrastructure, carry greater technical risk, have longer development lead times and are more costly to develop than has been the case during the past 30 years.

In addition to the above factors specific to oil and natural gas, developments in the financial market have also contributed to the rise in prices.

- The fall in the value of the U.S. dollar, relative to other currencies, has reduced the equivalent revenue available to oil exporting countries and also partially shielded other oil importing countries from the impact of rising dollar-denominated oil prices.
- Global investment funds are rebalancing their portfolios to include a higher portion of commodities, including oil and natural gas, and this trend has accelerated with recent weakness in equity markets.

Most of these factors are not controlled by or even much influenced by the actions of oil companies. However, our business is developing energy and delivering it to consumers in the most efficient and cost-effective manner we can. We will continue to strive to contain cost pressures and to deliver these energy products to consumers at competitive prices in a secure and reliable manner.

Today I will talk about three issues related to the energy future of America. First, the global demand for energy and the supply outlook. Second, the investments that Shell is making to increase energy supply. Third, actions that policymakers, like you, can take to address the energy challenge.

Energy Demand and Supply

The world will demand an additional 35 million barrels of oil per day by 2030, which is a 42 percent increase over today's demand. It will demand 64 percent more natural gas than we are producing now. The United States accounts for 25 percent of the world's energy demand. Americans use 10,000 gallons of oil – enough to fill a backyard swimming pool – every second of every day. We use 20 railcars of coal every minute.

These are sobering facts. How will this demand be met? Alternative and renewable energy sources will play a role and grow substantially. Energy efficiencies will improve as new technologies are developed and implemented. But leading experts forecast that oil and natural gas will continue to meet more than half of the world's energy needs in 2030.

As U.S. demand for oil and gas has been growing, U.S. production has fallen steadily for the last 35 years. Oil production in this country peaked in the 1970s. As U.S. consumption of oil has doubled, domestic oil production has fallen off nearly 40 percent. Why? In large part, this is the result of government policies that placed important oil and gas resources off limits. In 2006, the U.S. imported 3.7 billion barrels of oil to meet domestic demand, which is more than seven times the amount imported in 1970.

As we increased imports to meet our domestic energy needs, a new concept of "resource nationalism" was emerging in resource-rich nations around the world. This concept has changed the dynamics of global energy development. Thirty years ago, national oil companies owned by or affiliated with governments were either non-existent or small players. Today, these national oil companies own as much as 90 percent of the proven oil reserves in the world. While investor-owned oil companies – some of which are here today – hold just six percent of proven reserves.

So what is Shell doing? We are making significant capital investment to produce more energy – and more kinds of energy – to meet global demand. Enormous amounts of capital are required to fund our huge-scale projects and our cutting-edge research.

Let me share with you some statistics:

- Today, we have double the number of new projects under construction that we had in 2004.
- Last year, we spent some $25 billion on capital investment worldwide developing energy projects.
- This year, Shell will spend $28 billion to $29 billion – the largest capital expenditure program in the oil and gas industry.

Shell has invested in alternative and renewable technologies, as well as additional conventional and new unconventional energy sources.

Wind

Shell is becoming a significant wind energy producer. We are involved in 11 wind projects spread across the U.S. and Europe. The total capacity of these projects is around 1,100 megawatts (Shell share is about 550 megawatts) with 845 megawatts in operation and more than 260 megawatts under construction. Out of the total capacity, almost 900 megawatts are in the United States where we have wind farms in Texas, Colorado, Wyoming, California, Iowa and West Virginia. More wind farms are under development. Our activities focus on the development and operation of commercial-scale wind developments that can add significant power and capacity to the grid.

Solar

Shell is an international developer of thin-film solar technology. We believe thin-film technology – although in the early phases of development – could prove to be the most commercially viable form of photovoltaic solar technology to generate electricity from the sun's energy.

Biofuels

Shell is making a major commitment to the use of biofuels in transport fuels. Shell is the world's largest blender of biofuels by volume and one of the world's largest distributors of transport biofuels, at around 800 million gallons a year. Shell buys and sells 400 million gallons of ethanol a year in the United States, about 11 percent of the total U.S. ethanol production.

More important, however, Shell is a leader in the development of advanced biofuels technologies. Like most energy companies, we are engaged in the race to develop these technologies and fuels and make them commercially viable.

Shell believes that cellulosic ethanol holds particular promise. In the last six months, we have announced three new or expanded partnerships in cellulosic research and development projects in the United States, including fuel from algae and a promising new technology that could convert sugars directly to gasoline, rather than ethanol. This technology could potentially eliminate the need for special infrastructure and the low blend rates now required for standard vehicles.

Hydrogen

Shell is a leader developing transportation solutions with hydrogen. We are building hydrogen infrastructure in the United States, Europe and Asia. Right here in Washington, D.C., approximately three miles from Capitol Hill is the nation's first integrated gasoline/hydrogen station at our Shell station on Benning Road.

Gasification and Gas-to-Liquids Fuel
The Shell proprietary gasification technology is being used to convert coal and biomass into a cleaner fuel for power generation and other applications. We also have a leading position in Gas-to-Liquids (GTL) technology for the production of cleaner transportation fuels. Our Pearl GTL project under construction in Qatar will be the world's largest plant converting natural gas into transportation fuel. GTL from our plant in Malaysia is mixed with diesel and sold at 5,000 Shell stations in 11 countries.

Liquefied Natural Gas
Shell is an industry leader in the production of liquefied natural gas (LNG). When projects under construction in Australia, Sakhalin and Qatar are completed, our LNG production will have increased 80 percent above 2005 levels. In the United States, we have significant regasification capacity at two existing LNG terminals and plans for development of a new terminal in the Northeast.

It is important that we put these energy sources into proper perspective. As I mentioned earlier, alternative and renewable energy sources will not make a significant contribution to the energy mix for many decades to come. Therefore, Shell continues to make significant investment in producing and refining conventional oil and gas.

Oil and Gas
Exploration and Production: The Shell Exploration & Production (E&P) North American business is dedicated to growing the North American energy supply, a commitment underpinned by a history of investing billions each year, developing future domestic energy sources and defining new frontiers.

In the Gulf of Mexico, our exploration strategy is to drill prospects with large potential volumes and pioneer new plays. We are involved in a number of material prospects. Shell will continue to be an industry leader in the deepwater Gulf of Mexico, a frontier we pioneered more than a decade ago. In the past five years, we have produced nearly one billion barrels of oil there. The costs of deepwater exploration and production are immense and rising – from buying leases to bringing product to market. In November 2005, I told the combined panel of the Senate Energy & Natural Resources and Commerce Committees that the industry average cost of renting a deepwater oilrig was approximately $200,000 a day. Twenty-two months later, rigs were in such scarce supply that the cost of chartering one had climbed to more than half a million dollars a day. That was just the rig rental. The *total* daily costs of drilling a deepwater well – with the costs of pipe, support and all the rest – are even higher. In 2007, the average daily cost for a deepwater exploration well in the Gulf of Mexico was $759,000.

Shell is also pursuing natural gas prospects in a number of onshore North American basins. It is our goal to build new supply positions by developing both conventional and unconventional gas resources. Today Shell is drilling for new natural gas supplies in the Gulf of Mexico, Texas, and the U.S. Canadian Rockies.

Petrochemicals: Shell has a world-class manufacturing organization. By running our facilities safely, reliably and efficiently, we achieve consistently high levels of operational excellence that help us better meet customer demand. In the U.S., refineries operated by Shell and our joint venture, Motiva, currently have a refining capacity of nearly 1.4 million barrels per day. Motiva is spending around $7 billion to double the capacity of its refinery in Port Arthur, Texas. This project, when finished, will be one of the largest refineries in the United States and in the world. By adding 325,000 barrels-per-day capacity, the expansion is equivalent to building a new refinery.

Oil Sands and Oil Shale: Shell is investing in the technology and infrastructure to develop vast oil sands in Canada and oil shale in the United States. The Canadian resources can benefit the United States fuels market. Shell has a 25-year research and development program to access oil locked in shale rock in Colorado, Wyoming and Utah. Congress should pursue policies that ensure that these critical energy resources can be responsibly developed to help meet our nation's energy challenge.

This brings me to my closing point.

What policymakers can do to address the energy challenge.

I invite you to read the attached report, "A National Dialogue on Energy Security: The Shell Final Report," which highlights the findings of our tour across America. It lays out a 12-point plan to address future energy needs.

For today, however, let me highlight six points for you to consider.

First, I urge policymakers to look at the facts. Energy demand is rising to fuel economic growth. Oil and natural gas will be the major energy sources for decades, even as we grow new technologies. We cannot rationally decide among the hard choices ahead of us without understanding the basic issues of energy security.

This brings me to the second point. In general, the United States tends to resist the need to develop new domestic energy sources. Can we afford to continue this approach while energy demand and costs are rising? Oil and gas development can and should occur in an environmentally responsible way. In 2006, Congress took a significant step in opening some new oil and gas prospects in the Gulf of Mexico to exploration and development while, at the same time, providing those energy-producing states and local coastal communities in the region with a revenue stream to help ensure economic and environmental stability. Congress should extend Outer Continental Shelf revenue sharing for all coastal areas adjacent to offshore development and should make more areas available for offshore leasing.

Third, we need more than oil and gas to meet demand. We need all forms of energy – plus conservation and energy efficiency. I commend Congress for passing the Energy Independence and Security Act of 2007 with more stringent CAFE standards. These standards and the other provisions in EISA will do more to increase energy efficiency than any other piece of legislation in recent memory. Congress should continue to adopt policies that encourage conservation, and companies like ours must continue to think more creatively about products and services we can develop to help customers use less energy. Consumers – and that means all of us – must think more about our own energy footprints: when and how we drive, what we buy, how we work and the kind of world we want to create for coming generations.

Fourth, government agencies must have the staff and the resources needed to do the environmental analyses and other scientific studies that must underpin energy projects of all kinds. This data is critical and must be completed in a thorough and timely manner. Therefore, Congress should consistently authorize and appropriate funding for these key federal agencies to hire, retain or contract the expertise needed.

Fifth, Shell supports the adoption of a federal law to reduce greenhouse gases. Specifically, we support a cap-and-trade program coupled with sector approaches. Such a program must include policies that lead to commercialization of a carbon capture and storage (CCS) technology. Congress should ensure that we address CO2 emissions as we make the transition away from fossil fuels to new energy sources.

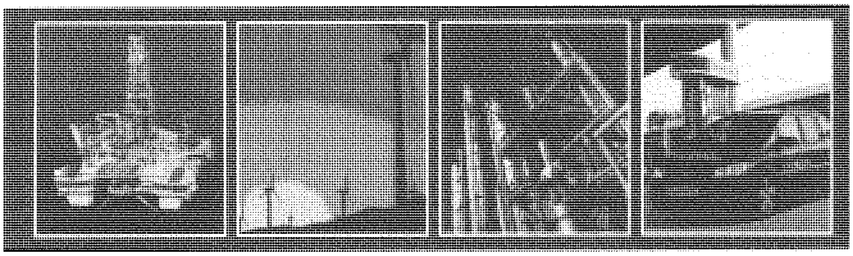
Finally, we need individuals skilled in math, science, technology and engineering to build the workforce of the future that will bring new energy sources to America. School curricula should include more study of energy – where it comes from, how it is used and the impact of the energy choices we make. And these lessons should begin at an early age, to shape consumer behavior and encourage curious young minds to become our next generation of energy engineers. We welcome Congressional initiatives that will help secure a future energy workforce.

I am aware that Chairman Markey has stated that the nation's energy challenge requires a commitment on the scale of the Manhattan Project during World War II or the space program of the 1960s. I agree with him. I am hopeful that policymakers, the private sector and the American people will come together on this important topic. We need to commit resources to all existing and potential energy sources, as well as innovations to address supply, demand and carbon footprint.

Thank you. I am happy to answer questions you may have.

A National Dialogue on Energy Security:

The Shell Final Report



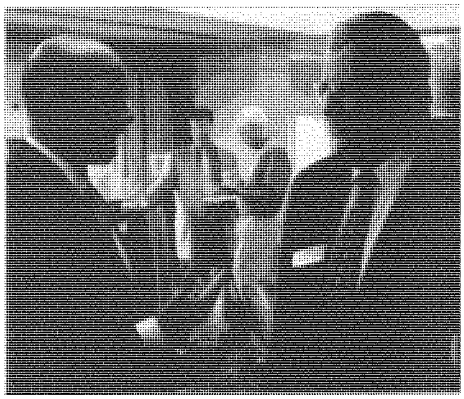
Nearly two years ago, Shell began a journey across America. We crisscrossed the country, traveling to 50 cities over 18 months and meeting face-to-face with thousands of people who are concerned about our energy future.

The dialogue was a transforming experience. We had hoped to build some bridges of understanding between the public and our industry. We succeeded. That meant that we educated some people about energy issues, but we also learned from what we heard and were changed – as individuals and as a company – in the process.

In this report, we want to share with you what we did and why, what we heard from Americans and what we learned in the process. Most importantly, we want to put some meaning around the experience – for Shell, for the energy industry, for policymakers and for everyone whose life is touched by energy. And finally, we want to issue a call to action for each American to find a role and a voice in shaping our energy future.

Listening to America's Concerns

"A National Dialogue on Energy Security," like many transforming ideas, was born out of frustration.



When already-rising oil prices spiked after the 2005 hurricane season, Americans were frustrated and openly hostile toward the oil industry. We were frustrated, too, by the level of misinformation and mistrust in the marketplace. Not just customers, but regulators and policymakers seemed to believe we were manipulating the market for our own purposes. Recognizing that our industry's ineffectiveness in communicating the key role we play in the global economy for the last decade had contributed to the situation, we decided to take action.

If lack of communication helped create the problem, we believed openness and transparency would help solve it. We created the dialogue with two goals: to build Americans' awareness of the energy issues we face, and to gain a better understanding of their perceptions and priorities. For us, listening was far more important than telling. Ultimately, we wanted to find a way that together we could work toward a secure and environmentally responsible energy future.

We visited 50 cities between June 2006 and November 2007. We delivered speeches at 53 events – luncheons, dinners, breakfasts – and hosted 38 town hall sessions where we asked community leaders to give us their priorities on energy resources and energy policies. We held smaller meetings with elected officials, non-governmental organizations (NGOs), students and educators. In all, we met with more than 15,130 Americans and conducted more than 100 local and national media interviews – potentially reaching a total of nearly 150 million people.

We asked audiences what we should be doing to increase domestic oil supply. We asked them what we should be doing as a nation to manage energy demand/consumption. And we asked them to describe their vision of the U.S. energy portfolio in the coming decade and beyond.

We listened – and listened – and listened.

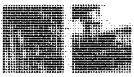
We heard Americans in every city say that they are struggling to come to terms with the new energy reality. The swing, within less than a decade, from $10 oil to $100 oil has clearly had a financial impact.[1] Yet few people were focused solely on bringing down the price at the pump. In fact, a surprising number of people suggested that the federal government should increase gasoline taxes to fund accelerated research into alternative fuels.[2] As one Philadelphia participant put it: "There's not enough pain to drive the market toward change... [we] need legislation, taxation and incentives."

And more people than we expected were aware of and concerned about environmental issues such as greenhouse gas emissions and climate change. "If we can't manage emissions," said one Fort Worth participant, "we need low emissions alternatives like renewables and nuclear." There was isolated support for concepts such as a carbon tax,[3] but little understanding of how approaches such as cap-and-trade might lead to emission reductions.

However, we found few who were ready to give up the comforts of an energy-fueled lifestyle. Most were hopeful that the solution could be found without forcing them to give up their SUVs, their solo commutes and the convenience of instant and unfettered mobility.[4]

We agree with the many Americans who told us that technology will provide the ultimate solution to balance energy and environmental concerns.[5] We heard high interest in and curiosity about hybrid and plug-in technology, hydrogen fuel cell vehicles and other high-tech solutions. As one Portland community

> *"We heard Americans in every city say that they are struggling to come to terms with the new energy reality. The swing, within less than a decade, from $10 oil to $100 oil has clearly had a financial impact."*



leader told us: "We need more energy engineers to achieve the correct balance between the need for more energy and the need to reduce CO_2 emissions."

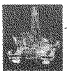
But many people were overly optimistic about how quickly we can make the technology leaps that are needed. When asked to envision the energy mix in a decade from now, estimates of the percentage of alternative fuels in the portfolio ranged from 10 percent to 100 percent.[6] Reflecting the same optimism, one Atlanta participant said, "With a Manhattan Project to develop this technology, the U.S. can be energy independent."

Regional Priorities

While priorities varied by region, nowhere in the United States did we find people who were indifferent to or unaware of the U.S. energy challenge. Clearly, the concerns are universal, regardless of where Americans live and work. But the regional "slants" to the energy challenge brought home to us even more the importance of understanding the day-to-day realities of the people we met:

> *"We found few who were ready to give up the comforts of an energy-fueled lifestyle. Most were hopeful that the solution could be found without forcing them to give up their SUVs, their solo commutes and the convenience of instant and unfettered mobility."*

- Northeast. Northeast residents emphasized conservation through utilizing new technologies, increasing the use of mass transit systems and educating Americans on measures to decrease their energy consumption. In the Northeast, we repeatedly heard the desire for increased government involvement and energy security policies: incentives and taxes and mandates to encourage individuals to conserve. There was also concern about the regions from which we receive oil imports, especially those from Middle Eastern sources, and we heard that residents wanted to increase our domestic energy independence.
- Northwest. In the Northwest, residents were strongly focused on conservation and new technology. Reducing demand was a priority, especially in Portland, where a "Peak Oil Task Force" has been formed by the city. In an area served by the Alaska pipeline, we did find support for increased access to Alaskan resources, with the caveat that environment and safety must be paramount.
- West Coast. Californians support diversifying the energy portfolio by further utilizing technology, an area in which the state has particular expertise, to solve the energy challenge, with a particular emphasis on renewables such as solar and hydrogen. To achieve this, they cited increasing renewable research and development activities in the public and private sectors, as well as looking at other alternative sources such as nuclear power. Residents focused on managing demand of fossil fuels through conservation, rather than increasing reserves to achieve energy security.
- Southwest. In the Southwest, we heard support for renewables such as wind and solar energy, resources that are abundant in the region. Nuclear energy was also a hot topic – some love it, some hate it. We also found high levels of interest in social action: energy education, energy-efficient communities, incentives to encourage conservation and use of mass transit. Residents also were interested in unconventional energy sources closer to home, such as oil shale, if they can reduce dependence on foreign oil.
- South Central. South Central residents, who are closest to the nation's oil-producing epicenter in the Gulf of Mexico, also seemed most pragmatic about the need to continue using fossil fuels in the near future. They were most likely to support increased domestic exploration and production. These residents also supported alternative fuels, clean coal technologies and stronger public policies on energy.
- Southeast. Further along the coast, in the Southeast, we found a focus on education. Residents want the public to be more aware of the current energy situation – and they also emphasized the need to educate elected officials. We found considerable support for increased access to domestic resources and greater refinery output, again balanced by a concern for safety and environmental protection. Clean coal and carbon sequestration were in the mix. We also heard a call for greater fuel efficiency,



through automotive technology improvements and Corporate Average Fuel Economy standards, commonly referred to as CAFE standards. Throughout the state of Florida, residents told us that they did not want, and would fight, new exploration and production off the Florida coast.

- Mid-Atlantic. In the Mid-Atlantic region, there was considerable emphasis on incentives for conservation and use of alternatives: higher gasoline taxes, legislated energy efficiency and promotion of hybrid vehicles. At the same time, we received support for increased domestic access to reduce our dependence on foreign oil.
- Rocky Mountains. Among Rocky Mountain residents, we found support for development of the region's oil shale resources with environmentally friendly technology. We also heard a call for incentives, taxes or "punishments" to promote efficiency and conservation. From elected officials, support for oil shale was mixed. Some described its development with enthusiasm, others more cautiously, but officials universally expressed the need to ensure environmental caution.
- Midwest. Midwesterners chose a middle ground. While there was slightly more emphasis on ethanol and biodiesel as an alternative to oil, in general participants were focused on educating both students and the general public and encouraging conservation. We heard support both for increasing domestic oil production and for diversifying the energy portfolio through alternative fuels.

A Life-changing Experience

When we chose to conduct a face-to-face tour, we understood the power of human interaction to break down barriers and change people. What we didn't expect was that we would be changed as much as our audiences were.

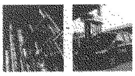
In room after room, we saw people respond to seeing the human side of "Big Oil." And it wasn't just the power of one person – there were 250 Shell leaders and professionals who participated in the tour in one way or another over its 18-month duration. People told us that they were surprised both by what we had to say and the effort we were making to reach out.

Over and over, skepticism … "When are you going to try to sell us something?" … turned to appreciation, and cynicism turned toward problem-solving. In Little Rock, one middle-aged man with a long gray ponytail came into the presentation clearly skeptical. His arms were crossed and his face was closed. But he listened. And when he heard what we had to say, the effect was visible in his entire demeanor. By the end of the question-and-answer period, he was smiling and nodding his head in agreement.

When tour attendees brought up climate change, we stated our response: "The debate is over. We are making changes in our business practices, and we are ready to work within a government-led framework that addresses greenhouse gas management, enabling markets to operate." It was a welcome message. Even a member of an environmental non-governmental organization in Tucson, who acknowledged that his organization was suing the U.S. government to stop Arctic development, also acknowledged his belief that the environmental behaviors exhibited by Shell are credible. As they left the town halls, people shook our hands and said, "This was time well spent."

We felt the same way. The experience was humbling – if anyone at Shell had ever considered that we could just tell our story and prescribe the answers to the American people, that mindset has now evaporated. The American people want to think through the issues themselves and apply their own reason and experience to the solutions. The experience reinforced for us how critical it is to get public policy right so that we can move forward in ways that Americans can feel good about.

> *"The debate is over. We are making changes in our business practices, and we are ready to work within a government-led framework that addresses greenhouse gas management, enabling markets to operate."*



> *"We also became more committed to the importance of a comprehensive national energy policy that addresses all facets of our energy path, from access to domestic resources to maintain our supply for the short term, through investments in the science and technologies that will meet our long-term needs."*

We started out believing that we were on the right track with our plans, and we still believe that. The message that we heard is that people are so greatly concerned about greenhouse gases and want energy companies to care about this as much as they do. This message reaffirms our commitment to this issue. We have signed on to the U.S. Climate Action Partnership to join our voices with others in establishing a national greenhouse gas management framework.

We also became more committed to the importance of a comprehensive national energy policy that addresses all facets of our energy path, from access to domestic resources to maintain our supply for the short term, through investments in the science and technologies that will meet our long-term needs. We heard a call for public policy to create a consistent framework within which individuals and businesses can operate. The Energy Independence and Security Act of 2007, which passed after the tour ended in November, is a partial move in the right direction, just as energy bills in 2005 and 2006 reflected partial steps. But there is much more that needs to be done.

What It Means

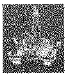
The message we heard from our conversations across the country was both heartening and frightening.

It was heartening to see that Americans are taking energy issues seriously. Attendance at events was high, and those who came were very engaged on the issue. After almost every speech, we spent almost as much time in questions and answers as in the presentation itself, and the questions, although sometimes quite pointed, were probing, legitimate queries from people seeking answers to a complex issue: "If the U.S. can't achieve energy independence, why push for more domestic production?" "Why aren't you investing more in alternative fuels?" "What is the timetable for oil shale?" People wanted to learn more about such areas as nuclear energy, unconventional oil and gas, and clean coal technology.

The practical recommendations we heard – from using education to help Americans understand the costs and consequences of energy choices, to providing incentives for energy efficiency – reinforced our faith in the common sense of American consumers and voters.

There was a futuristic bent, expressed best by one Louisville participant: "Realistically, what are the probabilities that new, cutting-edge research and technology will come along and create new sources of energy where none existed before, such as quickly and efficiently converting carbon waste back into crude oil or developing an efficient process for creating hydrogen?"

What was most frightening? The overwhelming disconnect between the perceptions of many consumers and the hard realities of the energy picture. This is the crux of our dilemma as a country in determining an energy path forward – the belief that there are easy answers that are readily available, when in reality the choices we have to make will not come easily or swiftly.



If we in America fail to differentiate between short-term and long-term situations, we will find ourselves at a crisis point while we wait for the long-term solutions to develop from experimental stages to commercialization. One insightful Portland participant realized that the question to ask is, "What energy bridges are we building today to get us from short-term to long-term solutions?"

This disconnect between future vision and current reality emerged in town hall comments such as the one we heard in Philadelphia. When we asked what we should be doing to increase domestic oil supplies, one response was, "Do nothing – we don't want more oil supply. We want to drive markets toward non-fuel energy sources." Yet of all the available solutions, doing nothing is potentially the most dangerous.

Unrealistic expectations were more the norm than the exception. This Minneapolis resident's vision of the energy mix a decade from now was not isolated: "We need to decrease our use of fossil-fuel-based sources by 70 percent to stem the trend toward global warming. I see a mix of solar, wind, biomass, along with greater efficiencies allowed through new technologies."

The anxiety around imported oil was clear. Those we spoke with recognized the risk that can come with dependence on sometimes hostile or unstable regions of the world for such a critical commodity. They see that the more than $2 trillion that importing nations, such as the United States, have paid to exporting nationals in the past five years for imported oil is a high price – especially when much of that money could be otherwise pumped into the U.S. domestic economy.[7]

"The anxiety around imported oil was clear. Those we spoke with recognized the risk that can come with dependence on sometimes hostile or unstable regions of the world for such a critical commodity."

Linked with this is a deep-seated fear of seeing the quality of life degrade for our children and their children if our ability to use energy is significantly constrained. In spite of this fear, there is still hesitation to embrace additional oil and gas infrastructure in our own country. "Nimbyism" ("Not In My Backyard") was present nearly everywhere.[8]

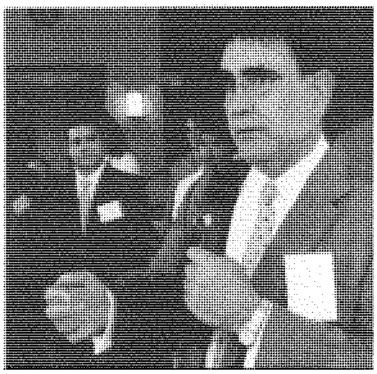
We also found a strong streak of visceral anger and zero sympathy toward the oil industry. We were somewhat prepared for this, based on the "hate mail" we had been receiving since prices first spiked in the post-hurricane supply shortage. However, when we probed, we found the anger stemmed from two sources: first, a simplistic view of the industry, based on the "Big Oil, big profits" image in the media; and second, a sense that the current situation was our fault – that if we had anticipated this demand, we could have increased the supply or pushed alternative technology faster. As one cynic in Portland put it, "Conservation could allow a new source of supply, but what's in it for Shell?" Many view alternatives as a way to curtail their uncomfortable dependency on the oil industry.

There was little confidence in the ability of either elected officials or corporate leaders to develop an effective solution. We found people more willing to trust non-governmental organizations – not necessarily as the possessors of the right answers, but as watchdogs that would keep government and business honest.

Anger also was directed against those perceived as using excessive energy. Participants in many cities spoke of "…punitive taxes for those driving gas-guzzling vehicles like SUVs." There was a sense of righteousness around this issue that was sometimes disturbing. One El Paso resident suggested that we should "force town hall attendees to arrive by bicycle, even in the rain."

This anger toward the industry and toward their fellow energy consumers can be a barrier to finding common solutions and can create a division between the energy "haves" and "have nots."

Fortunately, we found that open communication can alleviate some of the anger. Those who attended our presentations and town halls often left with a better sense of how global markets drive prices and how we have been working on technology solutions for years, even when prices were low. Governor after governor and mayor after mayor, while acknowledging infrastructure and permitting obstacles, invited new projects for their state or city for the jobs and economic improvements they could deliver.



The Disconnects – Seven Energy Myths

In our travels and discussions, we found seven major disconnects – areas where myths and misperceptions stand in the way of real solutions:

MYTH▶▶▶ 1. *The Myth:* **Oil prices are artificial.** We found this idea accepted among both individuals and government officials with whom we met. There is a belief that energy companies such as ours can set or even manipulate the price of oil higher or lower at will.[9] This leads to either expectations that oil companies acting independently can solve the energy problem (one participant suggested we "…raise the price of crude to enable unconventional sources"), or resistance to seeing the oil companies as participants in the solution. This attitude was reflected in one Charlotte resident's comment that, "The energy mix will not change – oil companies will reduce prices to keep alternatives out."

REALITY▷▷ *The Reality:* **Oil trades on a global market. Price is affected by supply, demand, fears and speculation like any other trading market. The price is very transparent.** The major oil companies (including Shell), despite being large, have relatively small shares of global oil reserves and production. Approximately 77 percent of proven oil reserves are under the control of national oil companies with no equity participation by foreign, major oil companies. The major oil companies control less than 10 percent of the world's oil and gas resource base.[10] These small shares ensure that private oil companies must behave competitively in the world oil market and cannot individually cut output and influence world oil prices. The Organization of Petroleum Exporting Companies (OPEC), an international cartel of oil-producing countries, is the single most important production-related entity. OPEC's objective has been to manage its members' collective supply through individual producer quotas in order to influence world oil prices.[11] The 13 OPEC member countries collectively hold more than 70 percent of proven oil reserves and produce about 40 percent of the world's daily consumption of crude oil.[12]

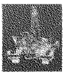
MYTH▶▶▶ 2. *The Myth:* **We're running out of oil.** The "peak oil" theory came up in nearly every market. While this wasn't necessarily surprising, the pervasive nature of this strongly held belief was. Similarly, in a related survey that we conducted, more than half of the respondents said global oil production will peak within the next 20 years.[13] This leads people to dismiss oil and gas from being part of the future energy portfolio. Also not surprisingly, we found that few people were aware of the scale of untapped domestic resources on the Outer Continental Shelf, or of the huge undeveloped unconventional resources, such as oil shale, oil sands and heavy oil.

REALITY▷▷ *The Reality:* **Oil resources are out there, should we choose to develop them.** When individuals think of peak oil, they tend to think that a sudden drop in global production follows soon thereafter. We don't expect to see this on a global level. It is possible, though, that we will reach a plateau in the next few decades, followed by a gradual decline of conventional oil and gas production.

There is no shortage of molecules of oil and gas in the ground. However, there are multiple influences that will affect the pace at which this can, and will, be developed.

On the demand side, we are seeing a step-change in the growth of demand for energy, particularly as emerging economies, such as China and India, enter more energy-intensive phases in their economic development.[14] It will be vital to become more efficient in how we use energy and to develop unconventional sources of oil and gas (such as oil sands), biofuels and vehicle electrification to meet this surge in demand. All energy sources added together will struggle to match demand – we will need all of the energy we can get.

On the supply side, many existing reservoirs are facing a natural decline in production. This means that high levels of continuous investment are required just to maintain status quo or to invest in enhanced oil recovery (EOR) techniques. In addition, ever-increasing levels of investment are required as smaller fields are developed and more complex frontier environments become the targets for hydrocarbon exploration and production, alongside the development of unconventional oil and gas supply. There are also uncertainties about the pace of investment in sensitive regions such as the Middle East and Latin America. Naturally, major resource-holding governments seek also to develop their sovereign reserves at a pace that matches their own economic goals.



There are plenty of uncertainties, which is why we explore future possibilities through scenarios. Looking at the oil picture, we find it misleading to think in terms of concepts like peak oil or try to put a timeframe to it. The significant economic point comes when tensions arise between the growth of global demand for energy and the pace of investment, production and supply. We believe we are entering such a period and will face this increasingly for some time to come.

◀◀◀MYTH

3. *The Myth:* **We have to choose between energy and the environment.** There is an assumption that we can't have conventional energy *and* a clean environment. As a result, we found that many policymakers want to block nearly all new access to existing resources on environmental grounds. One town hall participant shared this perspective: "We should not increase supply. We need to help find ways to reduce demand."

◀◀REALITY

The Reality: **The energy industry has made tremendous advances in finding ways to reduce the environmental impact of oil and gas production.** Few people realize the level of energy efficiency and environmental stewardship Shell and others have incorporated into every facet of exploration and production. Technology developed for offshore exploration and production has enabled us to reduce the environmental footprint of onshore operations. New construction techniques applied in the Gulf of Mexico enabled us to survive the 2005 hurricane season without a single major offshore oil spill. And improved emissions control technology has benefited the air quality around our refineries. New technologies such as "clean coal" can do even more to protect the environment, if we are willing to make the upfront investment.

◀◀◀MYTH

4. *The Myth:* **Importing energy is better than dirtying our own backyards.** In meeting after meeting, we heard resistance to new infrastructure from both community members and government officials. Especially in the Northeast, we heard complaints about high supply prices, and in the next breath a refusal to consider new infrastructure that would alleviate the supply bottleneck. The same infrastructure phobia has been applied to accessing domestic oil and gas resources. In several town halls as well as government meetings, we heard comments like this one: "Use foreign oil, and save ours for as long as possible."

◀◀REALITY

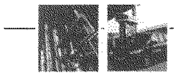
The Reality: **Environmental issues, especially issues of greenhouse gases and climate change, are global issues.** By using foreign supplies, we reduce our ability to manage and control the environmental impact. As one participant said, we need to "get rid of the 'not in my backyard' syndrome with regard to infrastructure and facilities." The United States is the only country in the world that restricts the use of its own energy resources while transferring trillions of dollars of wealth to other countries in order to import energy. In doing so, we demonstrate a narrow view of environmental protection. People we spoke with were shocked to discover the perverse nature of our public policy in this regard. For example, while the United States bans drilling within 125 miles off the coastline, Cuba is able to drill within 45 miles off the coast of Florida.[15] We agree with the many people we spoke with who urged us to move forward with "safe and environmentally friendly methods of tapping into the U.S. oil supply."

◀◀◀MYTH

5. *The Myth:* **Alternative fuels are a "magic bullet."** As noted above, the belief that alternative fuels can be widely available in the next decade presents a serious challenge to finding realistic short-term solutions. More than two-thirds of people we surveyed in a recent poll said that increasing the use of alternative fuels was the best way to ensure adequate supply while keeping the economy going.[16] Biofuels are viewed as an immediate possibility, hampered only by resistance from "Big Oil." At presentations and town halls, we heard John F. Kennedy's challenge to put a man on the moon quoted more times than we could count. We also heard recommendations from "...put a solar panel on every roof" – to achieve "...100 percent energy use from solar and wind and wave" – and to "...take the money that is currently being used to search for oil and use it to develop better alternatives to oil."

◀◀REALITY

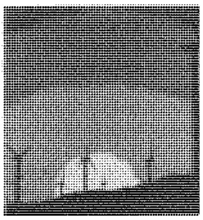
The Reality: **We believe in alternative fuels – but not in magic.** The International Energy Agency estimates that under a "business-as-usual" scenario, alternative energy will account for 8 percent of U.S. energy use in five years. It concludes that aggressive policies promoting alternative energy use could raise the percentage to 9.5 percent in the near term – well below what many respondents projected.[17]

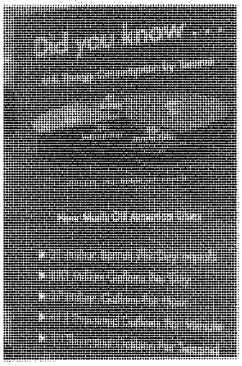


> *"But growing domestic ethanol production at this pace over the next five to 10 years will prove highly challenging. Food and other agricultural prices skyrocketed this past year in response to this new demand for corn."*

Shell has been investing significantly in alternative technologies since 1997, and we know that technology can be accelerated only so much. Some of the examples of the challenges:

- Solar. We had been in the silicon solar photovoltaic cell business since 1997, and we eventually realized that for Shell, the commercial feasibility of developing a material business in a reasonable time frame was doubtful. That business was sold. Now we are pursuing a new thin-film technology that promises to be much more efficient, but we – and others in this field – are far from being able to put a solar panel on every roof. Nor are consumers ready to pay the cost. Right now, solar energy costs between 20 and 30 cents per kilowatt-hour, up to three to four times the cost of other existing fuels for electricity generation.[18]
- Ethanol. In 2006, the United States produced 319,000 barrels a day (4.9 billion gallons a year) of this biofuel, mainly from corn. That is just a small fraction (3 percent) of the 9.7 million barrels a day of gasoline fuel consumers used in the United States during peak summer time. Ethanol production rose 19 percent between 2005 and 2006.[19] It is expected that 2007 data will show an even greater increase. But growing domestic ethanol production at this pace over the next five to 10 years will prove highly challenging. Food and other agricultural prices skyrocketed this past year in response to this new demand for corn. Cellulosic technology will produce more ethanol for sure, but the technology and timing, while legislatively demanded, are less certain.
- Wind. Audiences frequently cited wind power as a promising alternative. Shell has been heavily involved in wind as an energy source. We also view it as a viable alternative, but scaling it up to a significant level is a challenge. The American Wind Energy Association estimated in 2007 that the industry would install more than 3,000 megawatts of new wind generation infrastructure by year-end, and that about 31 billion kilowatt-hours (kWh) would be generated by wind power in the U.S. in 2007. While this is enough electricity to power the equivalent of nearly 3 million average homes, wind power currently accounts for less than 1 percent (0.65 percent) of U.S. electricity usage.[20] Scaling up is also challenged by the fact that many appropriate sites for wind turbines are located far from existing energy infrastructure, requiring development of additional transmission capacity as well.





Did you know . . .

- Hydrogen. Hydrogen is the world's most plentiful element, and is part of the Shell portfolio of future low-carbon fuels. As a fuel, hydrogen offers the potential to substantially reduce emissions and increase energy security. There are obstacles to be overcome, but hydrogen could become a commercially viable transport fuel in the coming years. Building on its strong technology platforms, we are developing low-carbon hydrogen supply chains, which in the longer term may rely increasingly on renewable sources of energy. We already have hydrogen fueling stations in the U.S., Europe and Asia and are working to develop mini hydrogen networks. We partner with car manufacturers and local governments to coordinate the building of hydrogen fueling stations in areas where fuel cell vehicles are being introduced such as the Los Angeles and New York City metro areas. Since 2004, Shell has operated an integrated gasoline/hydrogen station in Washington, D.C. and opened two new hydrogen stations in 2007: one in White Plains, New York, and another in Shanghai, China. We plan to open our first hydrogen station in Los Angeles in the spring of 2008.

Alternative fuels also require corresponding technology changes. Historically, it has taken 15 to 20 years for new automotive technology to move from concept to widespread commercial production.[21]

Plug-in electric cars or hydrogen fuel could play an increasingly important role in diversifying fuel choices in the transportation sector. Today, however, they only represent a small experimental place in the market. And in the meantime, many of the cars and trucks on the road today, and those that will be built in the next five to 10 years, will still be in use a decade from now or longer and will still rely on conventional fuels.

◀◀◀MYTH

6. *The Myth:* **We can conserve our way to energy security.** Many people cited conservation as the most important strategy. As one Pittsburgh resident saw the answer: "Penalties and sanctions for those who waste...incentives for those who conserve." Solutions ranged from adjusting thermostats and encouraging mass transit to "draining the last drop of oil from an oil can."

◀◀REALITY

The Reality: In our discussions, we have advocated a "culture of conservation" that relies on energy-efficient technologies, but that cannot be the full solution. Even to hold gasoline consumption at 2005 levels by 2020, assuming implementation of the new CAFE standards, will require the average American driver to reduce fuel consumption by about 20 percent – for example, by taking mass transit once a week.[22] That does not reduce our dependence on oil – it just maintains the line. And yet, as one Cincinnati town hall participant asked: "Who among us is willing to lay down their car keys and take mass transit?" Few hands went up when we asked for volunteers.

◀◀◀MYTH

7. *The Myth:* **Oil and gas companies make huge profits and are sitting on mountains of cash.** Oil and gas company profits are routinely front-page news after quarterly earnings announcements are published, leading to questions about what happens to all of that money and why energy prices are so high.

◀◀REALITY

The Reality: Oil industry profits are in line with other major manufacturing industries. In the U.S., for example, data compiled by the American Petroleum Institute (API) for the third quarter of 2007 shows the oil and natural gas industry earned 7.6 cents for every dollar of sales, compared to other industries such as beverage and tobacco products (21.6 cents earned for every dollar of sales) and pharmaceuticals and medicines (18.8 cents earned for every dollar of sales).[23] Additionally, over the course of the year Shell invested nearly as much as it earned in important new projects around the world to secure a sound energy future.

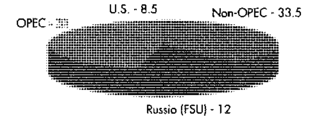
The "Razor's Edge" of Oil Supply and Demand – the Three Hard Truths

If the disconnects between energy myths and realities are the crux of the dilemma we currently face, the "Three Hard Truths" point us toward that razor's edge of energy supply and demand, adding even greater urgency for realistic solutions to our energy challenge for the short term, medium term and long term.

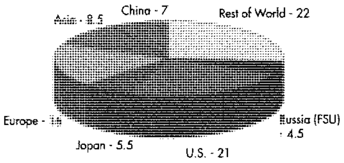
One: Global demand for energy is accelerating. A recent report by the National Petroleum Council looked at energy data and projections made by the U.S. Energy Information Administration and the International Energy Agency. From 1980 to 2000, world energy demand grew at about 1.7 percent per year. Since 2000, that trend has accelerated, driven by development in China and India coupled with continued expansion in developed economies.[24] The United States, however, still accounts for a quarter of global demand. We use 10,000 gallons – enough to fill a backyard swimming pool – every second of every day,[25] and 20 railcars of coal every minute.[26] Looking forward and assuming adoption of alternative policies, even the lowest projection shows that energy demand will continue to grow at 1.4 percent, while the highest projection is that demand will grow 2.5 percent.[27] At that rate, demand in 2030 will be more than double what it was in 2000.

Two: "Easy oil" will not keep up with demand. While we do not subscribe to the peak oil theory, the truth is that, particularly outside the Middle East, the readily accessible sources of conventional oil are being depleted.[28] To tap new resources requires hard choices. In some cases, that means spending more on exploration and development to find and tap ultra-deepwater resources as we are doing in the Gulf of Mexico. It means technology investments to convert oil sands to useable oil fluids as we are doing in Canada. And it means making the policy decisions necessary to grant access to areas where federal restrictions currently limit exploration and drilling.

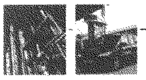
2007 Est. World Supply: 85 Million Barrels/Day



2007 Est. World Demand: 84.5 Million Barrels/Day



2007 Estimates - Energy Information Administration EIA



Three: Using more energy now means more carbon dioxide. We believe that by 2100, the world will have a radically different energy mix. The challenge is how we get there. Over the short term, most available energy sources are fossil-fuel-based. No matter where we obtain domestic or imported resources, our growing appetite for energy comes at a cost to the environment in the form of carbon dioxide emissions from both mobile and non-mobile sources. Without intervention, current government projections show that U.S. greenhouse gas emissions will rise 35 percent by 2030.[29] Around the world the rise will be as great, if not greater. Any path forward needs to include greenhouse gas management as part of the equation – thus the Shell position to support a comprehensive cap-and-trade policy led by government.

How Did We Get Here?

Over the 18 months that we conducted our dialogue, we were able to observe a growing understanding among Americans of some of the factors driving today's energy situation. In June 2006, audiences were still coming to grips with the reality of higher prices, and many were looking for someone to blame. Now, more of those we meet with are aware of some of the dynamics behind oil prices, as well as prices at the pump. But many still wonder how we reached this tipping point between supply and demand with so little warning.

Energy companies have to take some blame, primarily for a failure to communicate. One town hall participant asked bluntly, "How come we're not being informed about the problem and the alternatives?"

As an industry, we have not done a good job of building public awareness of energy issues.

> *"We have also been taken to task for not investing in alternatives long ago, but it was difficult to fund research and defend it to our investors when oil prices were so low that few would want to pay the high price for an alternative fuel."*

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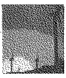
The factor that was not readily predictable was the pace of industrialization and associated oil-demand growth in developing countries, most notably China and India. As the National Petroleum Council report points out, these countries are just reaching the point where individual wealth and energy consumption start to accelerate. For example, the number of cars in China more than doubled between 2000 and 2006, although even with that increase, there is just one car for every 40 people. (Compare this to the United States, where we have one car for every two people.)[30] Oil trades on a global market so as these new demands put pressure on the supply, prices inevitably rise.

Geopolitical issues have also contributed to supply and pricing issues. Much of the world's oil resource is concentrated in countries that U.S. consumers consider unstable or sometimes even hostile. When the supply situation is already tight, as now, any supply disruptions – or the anticipation of supply disruptions – can push trading prices higher.

In the United States, partisan politics also have played a role by restricting access to otherwise produceable resources and making it difficult to build new infrastructure to address growing demand. Fortunately, Congress has begun to take action in some areas:

- In 2005, it passed the first energy bill in 13 years, which included incentives for increased oil and gas production in the Gulf of Mexico and a pilot program to cut the red tape for onshore exploration in approved areas of the western states.



- In 2006, Congress passed the Gulf of Mexico Energy Security Act, which opened 8.3 million acres on the Outer Continental Shelf off the coast of Florida for oil and gas leasing. The estimated resources in this area include 1.26 billion barrels of oil and 5.8 trillion cubic feet of natural gas. Although this area of the Gulf of Mexico is equivalent to a postage stamp on a newspaper page, it is the biggest area of the Outer Continental Shelf to be opened in more than 20 years.
- In December 2007, the President signed into law another energy bill. The Energy Independence and Security Act addresses fuel efficiency, renewable fuels, electric light bulbs and energy-efficient buildings, and begins to tackle greenhouse gas emissions. We believe there is still much more Congress can do, but the Bush Administration and legislators are to be congratulated for the positive steps they have taken.

We also commend groups such as the American Petroleum Institute (API), National Petrochemical and Refiners Association (NPRA), U.S. Chamber of Commerce, the National Association of Manufacturers (NAM), the American Chemistry Council, the United States Energy Association (USEA) and others that have been working to help develop solutions and educate the public about this issue.

The legislative actions mentioned above are important steps. But we must make it clear that they still fall short of a comprehensive, holistic, coherent national energy strategy that addresses short-, medium- and long-term solutions. Of the Outer Continental Shelf, 85 percent remains off limits.[31] We have moved forward on a $7 billion investment to expand domestic refinery capacity. However, the regulatory and permitting process is still a major barrier to refinery construction. The current policy also fails to address the promising area of unconventional fuels such as oil sands and oil shale.

Moving forward will require policymakers who are even more willing to take a tough stance on complex issues. We hope that we will not see one town hall participant's view proven right: "We may need more 'panics' to get people to act."

"In our view, the solution will require a coherent, comprehensive policy that addresses the full range of possibilities and finds the right balance among the options."

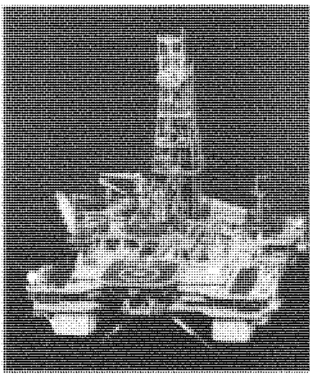
Solutions – A Twelve-point Plan

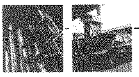
We've said before that we don't believe there is a magic bullet that will solve our energy challenges. In our view, the solution will require a coherent, comprehensive policy that addresses the full range of possibilities and finds the right balance among the options.

We need to think of energy security as one of three major security issues that we face and give it the same degree of attention we give to economic security (such as measures to address foreclosures due to subprime mortgage lending) and homeland security (such as heightened security measures following 9/11). Like these parallel issues, energy security warrants Presidential leadership, bipartisan congressional support, and a focus on solutions at the federal level rather than a patchwork of state programs.

Shell advocates a twelve-point plan that addresses three key areas: supply, demand and environment. As with many other 12-step initiatives, the first step is accepting that we have a problem. What we heard in our dialogue with Americans indicates that we have reached that point of acceptance.

> *Point 1:* **Allow more access to conventional oil and gas.** A Louisville town hall participant summed up the feeling we heard from many we met: "Keep pushing ahead on exploration and drilling technology; do whatever is necessary to protect the environment but do not give up on extraction from sensitive regions." In a survey conducted for us recently, more than seven in 10 people supported some degree of increased access to drilling in areas off limits to production.[32]
>
> At Shell, we are convinced that conventional oil and gas must be part of the solution in the short term, in the medium term, and in the long term. Having access to the more than 100 billion barrels of technically recoverable oil and gas in this country, with the responsibility to develop it using environmentally sensitive technology, can play a significant role in reducing our dependence on foreign oil sources.





Point 2: **Develop domestic unconventional oil and gas resources.** Canada already produces a million barrels a day of oil from the tar sands of Alberta.[33] In the United States, a trillion barrels of oil remain trapped in shale in Colorado, Wyoming and Utah.[34] Shell has been researching environmentally sensitive and commercially feasible ways of developing that resource, but our efforts are hampered by lack of a federal program that clearly defines regulations, policies and a royalty framework for development of this vast resource.

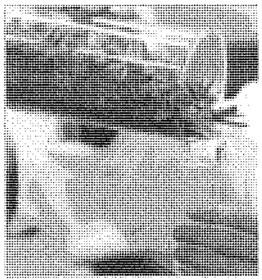
Point 3: **Move to clean coal technology.** The United States is rich in coal resources, but traditional coal generation produces high greenhouse gas emissions. Clean coal technology, otherwise known as coal gasification or IGCC (integrated gas combined cycle) technology, can allow us to use coal for electricity generation while capturing and sequestering carbon dioxide. This technology requires a larger upfront capital investment than traditional coal-fired electricity generation. Utilities and public utility commissions are challenged to define new ways of funding those investments that do not put an undue burden on shareholders or utility customers. National leadership in this regard can create the enablers to use clean coal and reduce carbon dioxide emissions.

> *"The new energy bill calls for expanding use of renewable fuels progressively from the current 4.7 billion gallons a year to 36 billion gallons in 2022. It will be a challenge for the industry to meet that standard, and it will require diversifying renewable fuels beyond corn-based ethanol."*

Point 4: **Supplement our natural gas supply with imported liquefied natural gas (LNG).** Most of the energy discussion focuses on lessening our dependence on imports, but natural gas demand is predicted to grow faster than our ability to develop further domestic production. Natural gas is becoming an increasingly preferred fuel for heating and electricity generation because of its clean-burning qualities.

Traditionally, natural gas has not been transported from one part of the world to another because of the difficulty of shipping a gas. Technology now allows us to store and ship the gas safely at extremely low temperatures in a liquid state. Imported liquefied natural gas is regasified at coastal terminals and transferred to existing pipeline systems. The challenge: resistance to infrastructure means that we face enormous difficulty in siting LNG regasification terminals, especially on the East and West Coasts. It will take ongoing education and forward-looking policymakers to make this clean energy source accessible.

Point 5: **Move biofuels beyond corn.** The new energy bill calls for expanding use of renewable fuels progressively from the current 4.7 billion gallons a year to 36 billion gallons in 2022. It will be a challenge for the industry to meet that standard, and it will require diversifying renewable fuels beyond corn-based ethanol. Already, the use of corn for fuel is affecting agricultural and food prices. We need to invest in the new infrastructure required to move, blend and distribute these billions of gallons of fuel, and governments – federal and local – need to assist with timely permitting. We need to pursue alternatives such as cellulosic ethanol, made from the stalks and other non-food parts of corn and other grains. Cellulosic technology is not yet ready for large-scale use, but it must be pursued aggressively to meet future demand without throwing other parts of the economy off balance.



Point 6: **Create the distribution systems to take advantage of wind energy.** Wind is one of the world's most benign energy sources. Shell now has interest in or operates seven wind farms in five states. But this technology is limited by lack of transmission systems to move the wind energy from remote hills and potential offshore wind farms to connect with the electric grid. These new systems need local permitting approval, which can be difficult to obtain – again, "Nimbyism" prevents the infrastructure. Federal and state policies supporting new transmission systems would enable this technology to be adopted more widely.

Point 7: **Push solar research to make it commercially viable.** After ten years in the solar business, Shell has learned a lot – mostly about what doesn't work or isn't commercially feasible. Available solar panel systems are too expensive and inefficient for wide usage. We are now looking to nanotechnology for a solution, but the right mix of efficiency, cost and availability remains elusive. Because the potential reward – readily available, zero-emission energy – is so high, this area deserves an intensive research and development push.

Point 8: **Develop the hydrogen fleet and fueling infrastructure.** Hydrogen as an automotive fuel is real today, but in a very small way. Shell is involved in a partnership with General Motors for hydrogen fuel cell vehicles, but it is still in the pilot stage, with demonstration projects in Washington, D.C., New York City and soon in Los Angeles. There are still technical and policy questions about permitting and regulation of a hydrogen fueling network. Hydrogen fuel cells also offer potential as a power source for electricity in buildings and homes. It will probably take a decade or more to make hydrogen a commercially available option. However, for our grandchildren's children, it may become the standard fuel of choice.

Point 9: **Focus on energy-efficient design.** Two-thirds of those we asked supported higher fuel efficiency standards and other government requirements for more energy-efficient products.[35] The national efficiency standards for light bulbs included in the 2007 energy bill are a significant step toward advancing energy efficiency. Ordinary incandescent bulbs use only 3 percent of their energy to create light – the rest is wasted as heat.[36] In the same way, automobile engines use only 20 percent of the energy they consume to move the car forward – the rest is wasted as heat.[37] The new CAFE standards call for greater fuel efficiency. Over the long term – not the short term – we may be able to achieve greater efficiency from a radical redesign of the power source than from shifts in fleet size and weight.

Energy efficiency also can be applied on a larger scale in urban planning. Many of our town hall participants stressed the need for development of "energy-efficient communities" or "smart growth" strategies designed around minimizing commuting.

Point 10: **Develop a federal framework for measuring and controlling greenhouse gases.** The energy bill of 2007 addresses some of the greenhouse gas emissions issues by adopting a stricter fuel economy standard for cars and light trucks, speeding up the use of energy efficiency technologies and increasing federal research for carbon capture and sequestration. These are important measures, but we believe a national climate change policy makes much better sense than dozens of regional policies or 50 state policies. On the present path and left unchecked, annual U.S. greenhouse gas emissions are projected to increase by 35 percent.[38]

A new report by McKinsey & Company identifies opportunities to reduce these projected emissions by between one-third to one-half in 2030 at manageable costs to the economy, using proven and emerging high-potential technologies – but only if the U.S. pursues a wide array of options and moves quickly to capture gains from energy efficiency. However, the report warns that private sector innovation and policy support will be necessary to unlock even the most economically beneficial abatement options.

Shell believes an effective U.S. climate change policy should:

- Include a workable cap-and-trade program for carbon emissions from stationary sources such as power plants and large industrial facilities and a separate program for reducing carbon emissions in the transportation sector,
- Encourage more renewable energies and the capture and storage of carbon dioxide emissions, and
- Work with existing international systems to reduce greenhouse gases around the world.

"Ordinary incandescent bulbs use only 3 percent of their energy to create light – the rest is wasted as heat."

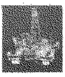
Point 11: **Educate our children and ourselves on energy issues.** In our national dialogue, we emphasized the need for both adults and children to be more educated about energy issues. More than two-thirds of those with whom we met supported funding for increased education and conservation awareness.[39] We cannot make the hard choices ahead of us without a broad understanding of the basic issues of energy security.

School curricula should include more study of energy – where it comes from, how it is used and the impact of the energy choices we make. And these lessons should begin at an early age, to shape consumer behavior and to encourage curious young minds to become the energy engineers of the future who will tackle these challenges.

Point 12: **Keep the door open for other technology solutions.** There are other viable energy alternatives, each with its own current limitations: nuclear power, geothermal energy and hydropower, for example. Nuclear power is a proven but controversial technology. For every town hall comment we received saying "more nuclear," there was a corresponding comment saying "no more nuclear." We need to keep pursuing these alternatives and look for other as-yet-undiscovered solutions.

Moving forward will require national political will, technological and human energy and major financial investments. But it can be done if we commit to act.

> *"We believe a national climate change policy makes much better sense than dozens of regional policies or 50 state policies. On the present path and left unchecked, annual U.S. greenhouse gas emissions are projected to increase by 35 percent."*



A Call to Action

In Philadelphia, one town hall participant responded to our dialogue with "a call for Shell to take the lead in an effort to support global energy policies that are not self-serving." This report begins a larger call to action for all of us: the energy industry, policymakers, business and community leaders and individual citizens.

It is critical that we continue to engage and participate in the debate around our energy priorities. There are hard choices to make to balance our energy needs, our economic well-being, our quality of life and our respect for the environment, not the least of which is an immediate and sustained need to embrace and accept new and updated infrastructure. We heard that no one wants solutions imposed upon them – they want to be engaged in the decision-making process. That requires ongoing education from leaders and experts, with an active response from communities and policymakers.

It will require government action to establish a legal framework that addresses:

- Access,
- Rights of ways,
- Permits,
- Regulations,
- Environmental stewardship,
- Appropriate safeguards, and
- Royalty structures.

"'The time is now and the American public is ready to take action.' Shell agrees."

Congress has made a positive start with the energy bills of 2005, 2006 and the Energy Independence and Security Act of 2007. There will be a cost to achieving our energy security, and it must be shared fairly among all involved. For businesses and shareholders, this will mean making appropriate investments in technology and pushing innovation that can advance our energy security.

Every American has a stake in this issue and a role to play. We each must look at our own carbon footprint and determine if we are making the best use of the energy we consume. Each of us as individuals must make our voice heard to shape a future path that reflects our values and priorities.

In this presidential election year, we all have a responsibility to understand the dilemma we face, the complexity of the choices and the fact that there are no easy answers. We must ask our candidates about their stands on energy security in the short, medium and long term and push for comprehensive energy solutions that make sense for the economy and the environment.

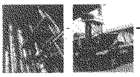
As one Cincinnati participant said, "The time is now and the American public is ready to take action." Shell agrees.

John D. Hofmeister, President

Shell Oil Company

February 14, 2008

For more information on what is required to ensure energy security, visit: www.usenergysecurity.shell.com.



A National Dialogue on Energy Security: The Shell Final Report

Endnotes

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[1] *U.S. Energy Information Administration*. "World Crude Oil Prices," weekly histories (Feb. 2008).

[2] Thirty-four percent of Shell town hall attendees "strongly supported" increasing the tax on gas and using the money to invest in energy conservation and alternative energy options. (October – November 2007 follow-up phone survey) This concept also appeared frequently in verbatim town hall comments. Town hall comments are posted at www.usenergysecurity.shell.com.

[3] Town hall comments.

[4] When forced to choose one of two statements, 61 percent of town hall attendees agreed that "even if it means significant changes to our lifestyles, we need to reduce our dependence on oil"; 39 percent agreed that "we will never really change our lifestyles, so we need to find new sources of energy, whether fossil fuels or something else." Yet in a separate question, only 31 percent identified "conserving energy" as the most important action to help ensure adequate energy supply. Forty-seven percent supported increasing alternative energy use; 22 percent supported increasing energy supplies. (Source: follow-up phone survey)

[5] Based on town hall comments. In addition, a survey of the general population conducted in October-November 2007 paralleling the town hall follow-up survey showed that 67 percent identified alternative energy use as the most important action to ensure an adequate energy supply in the future.

[6] Town hall comments.

[7] *U.S. Energy Information Administration*. "EIA Short Term Energy Outlook." Updated January 2008.

[8] Based on town hall comments and meetings with government officials.

[9] Based on town hall comments. Profits/price gouging was also identified as the "biggest issue facing the oil industry today" by 7 percent of the general population surveyed.

[10] Jaffe, Amy Myers. "The International Oil Companies" (The James A. Baker III Institute for Public Policy, Rice University) (2007).

[11] Jaffe, Amy Myers, et al. "U.S. Energy Policy FAQ: The U.S. Energy Mix, National Security and the Myths of Energy Independence" (The James A. Baker III Institute for Public Policy, Rice University) (2008).

[12] *Organization of the Petroleum Exporting Countries (OPEC)*. Annual Statistical Bulletin 2006 (2007).

[13] In the town hall survey, 30 percent of respondents predicted global oil production would peak in less than 10 years; 28 percent predicted it would peak in 10-19 years. The general population responses were even higher: 33 percent and 35 percent respectively.

[14] *International Energy Agency*. "World Energy Outlook 2007: China and India Insights, Executive Summary" (2007).

[15] Snow, Nick. "Bush asked to recall US-Cuba boundary delineation note." *Oil & Gas Journal* (volume 106, issue 5, 4 Feb 2008): citing the 1977 U.S.-Cuba Maritime Agreement.

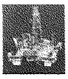
[16] See endnote 4 above.

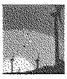
[17] *International Energy Agency* data cited in Jaffe, Amy Myers, et al. "U.S. Energy Policy FAQ: The U.S. Energy Mix, National Security and the Myths of Energy Independence" (The James A. Baker III Institute for Public Policy, Rice University) (2008).

[18] Jaffe et al., *op. cit.*

[19] Ibid.

[20] Ibid.





[21] Ibid.

[22] Ibid.

[23] *American Petroleum Institute.* "America's Oil and Natural Gas Industry: Putting Earnings into Perspective" (2008).

[24] *National Petroleum Council.* "Facing the Hard Truths about Energy: A comprehensive view to 2030 of global oil and natural gas" (2007).

[25] Lovins, Amory B., et al. "Winning the Oil Endgame: Innovation for Profits, Jobs, and Security" (Rocky Mountain Institute) (2004).

[26] *U.S. Energy Information Administration.* Total U.S. coal production in 2006 (latest data) was 1,112.3 million tons. A railcar holds 100 tons.

[27] *U.S. Energy Information Administration*, "International Energy Outlook 2006," and *International Energy Agency*, "World Energy Outlook 2006," cited in "Facing the Hard Truths about Energy."

[28] *International Energy Agency*, "World Energy Outlook 2004," cited in "Facing the Hard Truths about Energy."

[29] *McKinsey & Company.* "Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?" (2008).

[30] *NPC*, op. cit.

[31] *American Petroleum Institute* estimate based on data from U.S. Minerals Management Service, U.S. Geological Survey, Bureau of Land Management, and National Petroleum Council.

[32] In the October-November 2007 general population survey, 15 percent of respondents supported "significantly reducing restrictions" in Alaska, 15 percent in U.S. coastal waters, 11 percent on federal lands and 44 percent on "all of the above."

[33] *Alberta Energy*, Government of Alberta, (http://www.energy.gov.ab.ca/OurBusiness/oilsands.asp) (8 Feb. 2008).

[34] "Oil Shale Development in the United States: Prospects and Policy Issues." Rand Corporation study for the National Energy Technology Laboratory of the U.S. Department of Energy (2005).

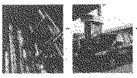
[35] In the October-November 2007 surveys, 64 percent of town hall attendees and 63 percent of the general population "strongly supported" requiring more energy-efficient products. Requiring automakers to produce cars and light trucks that get better fuel mileage was strongly supported by 64 and 67 percent respectively.

[36] *Wikipedia.* Incandescent light bulb entry, (http://en.wikipedia.org/wiki/Incandescent_light_bulb) (8 Feb. 2008).

[37] *FuelEconomy.gov*, United States Department of Energy, (http://www.fueleconomy.gov/feg/atv.shtml) (8 Feb. 2008).

[38] *McKinsey & Company*, op cit.

[39] In the town hall survey, 69 percent "strongly supported" increasing conservation awareness and education for citizens.



"If lack of communication helped create the problem, we believed openness and transparency would help solve it. We created the dialogue with two goals: to build Americans' awareness of the energy issues we face, and to gain a better understanding of their perceptions and priorities."

Tell us what you think about Shell, our performance, our reports or the issues we face in the U.S. and globally via email at **shloil-tellshellus@shell.com**

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The CHAIRMAN. Thank you, Mr. Hofmeister.

Our next witness is Mr. Peter Robertson, who is the Vice Chairman of Chevron. He has served as Vice Chairman of the board of Chevron since 2002. He has spent 15 years with that company.

We welcome you, sir.

STATEMENT OF PETER ROBERTSON

Mr. ROBERTSON. Thank you.

Good afternoon, Mr. Chairman, Ranking Member Sensenbrenner, and members of the Committee. My name is Peter Robertson, and I am Vice Chairman of Chevron Corporation, and I am here today proudly representing 59,000 Chevron employees, 27,000 of whom work here in the United States.

I appreciate the opportunity to discuss the energy issues that are very much on your minds and those of all Americans. I will address three issues: rising oil prices; our commitment to providing energy, including renewables; and policies to insure that we enhance our energy security.

Four years ago we sent a letter to members of Congress, the administration, cabinet members, as well as trade associations and think tanks. It foreshadowed the issues we face today and included concrete ideas for action. The letter said we face a new reality: volatility, high prices, greater competition for resources, and heightened geopolitical risks.

Today this new reality is here, and it is costing us. All Americans feel the pain of $100 oil, and it is not just at the pump. Everything is more expensive. People are concerned about rising costs and rightly so.

The world is consuming oil at an ever increasing rate, and it is projected to continue. There are a billion people who enjoy our standard of living, and there are billions more striving for the same.

The current system is straining to meet their needs. There is dramatically reduced spare capacity, and there is no room for error. Any disruption or perceived threat of disruption typically sends prices up, and the declining value of the dollar has only worsened the situation. The situation is not sustainable, and it is time to take urgent action.

So what are we doing? Chevron produces almost one billion barrels of oil equivalent a year, and as large as that number sounds, it serves less than three percent of world demand. And in the U.S. our refineries produce six billion gallons of gasoline each year, another large number, but that is less than five percent of America's gasoline consumption.

Between 2002 and 2007, Chevron invested approximately $73 billion in new energy supplies, more than we earned. This year we will spend another $23 billion, including 2.3 billion in U.S. refining and marketing activities. We have added one million gallons a day in gasoline capacity over the last two years.

Let's talk about renewable energy. Today Chevron is the world's largest producer of geothermal energy. Between 2007 and 2009, we plan to spend $2.5 billion on renewables and energy efficiency services. We formed a range of partnerships to pursue next generation biofuels. Let me give you one example.

We teamed up with Weyerhaeuser Corporation because we need partners. They know plants; we know fuels. Together we provide the unique combination necessary to meet this challenge.

But it will take time to have a meaningful impact. A large biofuels plant in the U.S. produces in a year what one of our refineries produces in a single week. The enormous scale of the energy system means that we must continue to bring traditional energy supplies to market even as we accelerate the development of renewables.

But increasing supply is only one important step. We also need to aggressively moderate demand. America needs to become a nation of energy savers. Chevron Energy Solutions has completed more than 800 energy efficiency and renewable energy projects, largely in public facilities, reducing emissions and saving on average nearly 30 percent in energy and operational costs.

In closing, I want to emphasize what we can do together to help consumers. The National Petroleum Council study involved 1,000 participants, scientists and NGOs, industrial consumers, and policy experts. It recommended five strategies ranging from moderating demand to expanding supply, to increasing research. It has given us sound, sensible, achievable solutions. Now we need action.

We strongly urge you to implement its recommendations, but first we need to change our nation's conventional wisdom about energy development and use. On the demand side, our country needs to value energy as a precious resource. We need a "made in America" solution enabled by everything from human ingenuity to smart buildings, to advanced vehicles.

On the supply side, we need to be sensitive to the scale and time frames required to alter the energy mix. We need to help to open up the 85 percent of the outer continental shelf that is off limits. We cannot expect other countries to expand their resource development to meet our need as we limit our development without good reason.

And we need your help in dealing with inefficiencies in the gasoline market. There are 17 boutique fuel requirements across the country. More requirements on fuels are being added through renewable fuel mandates and proposed climate policies. These important policies must be advanced in a way that Americans can afford.

The time for action is now. During the five minutes it took me to deliver my remarks, the world has consumed the energy equivalent of 35 million gallons of oil equivalent. Our collective leadership and ingenuity can set a path for true progress.

At Chevron we will continue to do our part.

Thank you very much.

[The statement of Mr. Robertson follows:]

Peter J. Robertson
Vice Chairman
Chevron Corporation
Statement Prepared for the House Select Committee on Energy Independence and Global Warming
April 1, 2008

Chairman Markey, Ranking Member Sensenbrenner, Members of the Committee. My name is Peter Robertson, and I am vice chairman of Chevron Corporation. I am here to represent the more than 59,000 Chevron employees (of whom 27,000 work here in the United States) and more than 1.5 million stockholders who put their trust in our company each day. I am proud to be a part of an industry so vital to every American's way of life and to the development and growth of economies around the world.

Given the many challenges our country faces on the energy front, I appreciate the opportunity to appear before you today. I will address the factors behind rising oil and gasoline prices, highlight what Chevron is doing to develop alternatives and traditional energy sources, and discuss the type of policies that promote the use of renewables and provide long-term energy security for Americans.

Although Chevron has been firmly rooted in California for almost 130 years, our operations and customers span the globe and extend across the entire energy spectrum. Globally, we produce 2.6 million barrels of oil- and gas-equivalent per day—less than 3 percent of global oil and gas volumes. Chevron's U.S. production of approximately 765,000 barrels of oil- and gas-equivalent per day represents roughly 5.4 percent of U.S. total.

We refine, transport and sell petroleum products. Chevron is the sixth-largest refiner in the United States, producing about 4.8 percent of the country's gasoline. And we blend ethanol into almost 40 percent of the gasoline we sell in the United States.

Chevron is a leading producer of renewable energy. We're the world's largest producer of geothermal energy (operating 1,250 megawatts), and we're pursuing next-generation biofuels and other alternatives with a number of important strategic partnerships.

Chevron is also a major provider of energy efficiency services and clean energy solutions in the nation. Our subsidiary Chevron Energy Solutions has a strong track record of providing solar power to large commercial clients across the country. To date, it has handled more than 800 projects, saving clients on average 30 percent on their energy consumption and operational costs.

Chevron strives to be a strong partner in the communities where we operate. Our company supports more than 11,000 large and small businesses throughout the country. Last year alone, we spent $10.8 billion with our business partners in the United States.

It is precisely Chevron's size and scope that allow us to take risks in an environment in which global resources are increasingly nationalized, and single oil and gas developments run in the billions of dollars. The search for the next source of energy—whether it be oil or next-generation fuels from renewable sources—takes enormous capital, specialized expertise and the organizational capability that characterizes Chevron. Transforming raw materials into useable energy products and delivering them to markets on six continents takes substantial financial strength, advanced technology and human energy.

And yet, from a global perspective, sovereign states and their national oil companies own 94 percent of the resources consumers need. Chevron ranks 21st in terms of its access to oil and gas resources (*See Appendix chart #1).*

Strong global demand, weak U.S. dollar have driven up oil prices

As we meet today, the price of oil has risen recently to record levels above $100 a barrel. Given that the largest contributor to the cost of gasoline is crude oil, this has translated into record-high gasoline prices. In February, according to the Department of Energy, a gallon of regular gasoline retailed on average for $3.03; the price of crude oil accounts for some 70 percent of this, or about $2.11. Federal, state and local taxes averaged 40 cents per gallon, making the combined effect of crude costs and taxes $2.51 per gallon, or 83 percent (*See Appendix chart #2).* Consumers and businesses feel the effects from the supermarket to the airport. Likewise, in the energy industry, we are feeling the effects—from increased energy costs to produce, refine and distribute products to more expensive steel to costlier rates for drilling ships. We are as concerned about escalating oil prices as any other energy consumer. To address these concerns going forward, it is important to understand the many factors affecting the price of oil—and, therefore, the price of transportation fuels.

There are fundamental factors affecting the current price of oil, including rising demand, the reduction in the supply system's spare capacity to deal with unforeseen disruptions, the value of the U.S. dollar and the associated flight to commodities, and rising risk—both above ground and below ground.

We have reached a point where worldwide demand is straining the global energy system. While demand in OECD countries essentially has been flat over the past few years, demand in non-OECD countries—what we typically think of as developing nations—is experiencing robust growth. In fact, growth in non-OECD regions has accounted for over 80 percent of the rise in oil demand since 2000. China's new "Industrial Revolution" has lifted all boats across non-OECD economies, especially Asia. The expansion has been driven by exports and infrastructure investment, and has consumed commodities at an unprecedented rate. It is important to highlight that in many important energy-consuming non-OECD countries government treasuries have subsidized price *(Appendix chart #3)*, a factor that has contributed to additional stress on supplies and price.

The Middle East is also in the middle of a substantial investment cycle, a process that has kick-started oil demand growth in the face of rising oil prices. Thus far, non-OECD oil demand growth has shown few signs of softening despite the U.S. economic slowdown.

It is this economic growth overseas, especially in India and China, that has helped hundreds of millions of people to rise above the poverty level to a better quality of life. These basic human aspirations and the associated energy growth are forecasted to continue. Global energy demand is projected to increase roughly 50 percent by 2030, with demand in the Asia-Pacific expected to grow 90 percent over the same period *(See Appendix chart #4)*. And, according to the Department of Energy, demand in the United States is also forecasted to grow by 16 percent over the next 20 years *(See Appendix chart #5)*.

The accelerated increase in demand since 2004 has reduced the global spare capacity of oil, creating a tighter relationship between supply and demand and heightened concerns in markets around the world *(See Appendix chart #6)*. Falling or flat U.S. production is a contributing factor and adds to these pressures. According to the Department of Energy, U.S. oil production has fallen approximately 40 percent since 1985, while U.S. consumption has grown more than 30 percent. In real barrels, U.S. oil production is now below 5 million barrels per day—it was approximately 9 million in 1985. The narrowing of spare production capacity in the world means that even when a relatively small amount of resource is at risk of disruption due to a variety of factors, it can affect the price of oil.

This heightened market sensitivity is exacerbated by other risks. "Below ground risk" is increasing as energy is harder to find and more expensive to produce. "Above ground risk" is also occurring around the world. At home and abroad, access to new supplies has been restricted, making it increasingly difficult for the energy industry to invest and expand operations. And calls for increased taxation only serve to shrink the capital base available for energy development. As the recent National Petroleum Council study pointed out, our country's greatest concern relative to future supplies stems not from a lack of hydrocarbon resource but, rather, from the risks to our ability to expand production in a manner timely enough to meet growing demand. Policies restricting access to new areas with resources in the United States combined with naturally declining mature oil and natural gas fields have increased U.S. reliance on supplies from international sources.

These factors are not a new phenomenon. It has been something Chevron has been warning Congress about for some time. In 2004, we sent a letter to the administration and leading members of Congress, trade associations and leading think tanks that said: "Today, we face a new reality in energy—one characterized by volatility, high prices and greater competition for resources that are shifting traditional alliances. Increased and sustained demand from China and India, declining supplies of traditional energy sources, and heightened geopolitical risks in the critical energy producing markets have contributed to this new reality in energy."

This new reality and the impact on oil prices are compounded by the weakening of the U.S. dollar. The higher oil price is in part a market adjustment that reflects the weakening purchasing power of oil exporting countries that sell their oil in U.S. dollars but buy goods with stronger currencies such as the euro. Additionally, the weak dollar—and concern by stock investors over the subprime issue and its impact on the stock market—has contributed to a flight to commodities by investors seeking better returns *(See Appendix chart #7)*. Oil has gone up along with many other commodities such as gold, corn, copper and even coal. While oil has reached record highs this year, a *Washington Post* article on March 20 reminds us that the tightening global energy-supply demand balance also has affected coal, which has increased in price by approximately 9 percent since the beginning of the year.

This has created a somewhat unusual situation that was observed by one economist speaking to the *Wall Street Journal*: "Crude futures prices," he said, "have decoupled from the forces controlling the underlying physical flows of the commodity." Or, more simply put, the weak dollar keeps prices high, even though the market has responded both with more supply to meet demand and, in some sectors, a lowering of demand. In fact, recent figures from EIA suggest that demand in the United States has moderated in response to the current high prices. That prices still remain high underscores the fact that many factors are in play and there are no short-term fixes to today's price levels.

Energy challenges are immense – so is the infrastructure needed for supplies

To understand today's energy reality, I would emphasize that the energy system is global, vast and complex. For each minute we spend here today, the world will consume the equivalent of 7 million gallons of oil-equivalent. For decades it also has delivered energy to over a billion of people around the globe efficiently and reliably. The infrastructure that produces energy in one part of the world and delivers it to another is highly interconnected—physically and to the global markets that set price. Each depends upon the other. Although the United States is a key producer and *the* leading global consumer, we are only one part of this global system and cannot be isolated or immune from issues that either shape or upset global market dynamics.

There has never been a more urgent need to be realistic about the energy system's *inter*dependence and its size and scale. We also need to recognize the magnitude of resources, both financial and organizational, needed to keep it running. Today's energy infrastructure requires substantial ongoing investment to sustain production, tap new sources and meet growing demand. In fact, in its 2007 Energy Outlook, the International

Energy Agency has projected that the world will require $22 trillion in new energy investments by 2030, with $7 trillion needed to produce the resources—the oil, natural gas, coal and biofuels—needed to meet demand. Nearly half of these investments will be in developing countries.

As we strive to meet demand, we are overcoming increasingly extreme and remote environments, and we are facing head-on the challenges posed by climate change. Our industry has evolved over the last 100 years from relatively simple wooden derricks that barely scraped the Earth's surface to complex offshore platforms that produce oil from reservoirs located miles below, where pressures can exceed 20,000 pounds per square inch and temperatures well surpass the boiling point. One new oil project on the frontiers of the Gulf of Mexico can cost more than $5 billion and take more than 10 years to bring onstream. But one of these projects adds less than 1 percent of U.S. demand and illustrates an industry truism: The era of easy oil is over.

There are significant challenges that need to be resolved so that we can generate the kind of production at a scale needed to meet U.S. demand. These challenges will take time, money and new infrastructure and technology to solve. For the foreseeable future it also will take contributions from all energy sources—traditional energy and renewables and alternatives.

Biofuels offer an important resource in the future of transportation fuels. The challenge is one of commercial scale. One of the country's largest biodiesel facilities, located in Washington state, for instance, has an *annual* production capacity of 100 million gallons. This amount would serve the country's demand for transportation fuels for about six hours of one day. And it roughly equals the amount of transportation fuel that Chevron's refinery in Pascagoula, Mississippi, produces *in a single week,* and Pascagoula is one of approximately 150 refineries in the United States. This illustrates the kind of scale needed for biofuels to have a meaningful impact on the energy mix that serves the transportation needs of an economy the size of the United States.

Renewables and alternatives represent less than 10 percent of the global energy mix today and have seen a fourfold increase in global investment since 2004. Nearly $150 billion has been poured into this sector in the past 12 months alone (*See Appendix chart #8).* The volume of renewables is expected to increase roughly 45 percent by 2030 to meet demand. Even so, their percentage of the total energy mix will remain close to the current percent, because the overall global demand is growing so quickly.

Chevron is aggressively investing to develop new energy supplies

We are actively responding to the energy demand of the United States and countries around the world—investing aggressively to develop energy supplies to meet today's and tomorrow's needs. Our activities span a diverse portfolio of energy interests, including traditional oil and gas, renewables, alternatives, energy efficiency services, and research and development in future energies. Between 2002 and 2007, Chevron invested approximately $73 billion back into the business to bring new energy supplies to market—investing what we earned. Some $17 billion of that sum was invested in our U.S. upstream—or exploration and production—operations.

Our capital program for 2008 is close to $23 billion, an increase of nearly $3 billion over our 2007 investment, and nearly triple what it was in 2004. Globally, Chevron currently has 40 major oil and natural gas capital projects in the planning or development stage, each with a net Chevron share of the investment of over $1 billion. These projects are critical to supplying the energy that the world needs and will be important to closing the gap between supply and demand, which is key to addressing the challenge of high prices. Out of this queue of 40 major supply projects, eight are located in the United States. And there are many other upstream projects under $1 billion that will have significant production once they come onstream *(See Appendix chart #9).* A number of these projects are situated at the forefront of development and employ leading-edge technology. As alluded to earlier, factors such as size, organizational capability and the ability to assume the inherent risks in developing technology and undertaking large investments are essential assets when competing in today's global energy environment. Even though Chevron is relatively small compared with its nationalized competitors, it is a strong competitor. This is an industry in which size, technological capabilities and financial strength are the new "price of entry," and large-scale and frontier energy developments are the norm, not the exception, today and in the future.

Let me highlight a few key projects to illustrate what we do. We are working on several deepwater oil and natural gas projects in the U.S. Gulf of Mexico. One of these, known as Tahiti, offers a typical case study in the risks facing this business today in terms of timing, scale and cost. We acquired the Tahiti leases in the 1990s, when oil was in the $20 per barrel price range. In 2002, we used leading-edge technology to drill in 4,000 feet of water and found an estimated 400 million to 500 million barrels of recoverable resources. It will take seven years to build the infrastructure required to produce the oil and gas more than a 100 miles offshore. When Tahiti finally comes on line, we will have invested $4.7 billion—before realizing $1 of return on our investment. Once in production, Tahiti is expected to produce for up to 30 years. At it peak, Tahiti is expected to add 125,000 barrels of oil and 70 million cubic feet of gas per day to the U.S. domestic supply.

Another example is a research and development project on refining technology our company recently announced. Known as VRSH, which stands for Vacuum Resid Slurry Hydrocracking, this technology will help us produce transportation fuels from heavy oil otherwise used for other lower-grade petroleum products. We spent almost five years working on the project in a lab setting testing the technology. We announced in March that we are beginning work on a pre-commercial plant at one of our U.S. refineries that will take two years to construct. We will learn more about the technology for a few years before we will be able to confirm whether we can build one of these plants at full scale. Once that decision is made, it will take another several years after that to complete. This kind of step-by-step process is needed to ensure we are making the right decisions. They take time.

A final example is our Kern River oil field in southern California. We discovered oil more than 100 years ago in the San Joaquin Valley. At Kern River, 2 billion barrels later, we are still there. This year we expect to spend nearly $1 billion on the sophisticated technology and ongoing development activities required to produce as many barrels as possible out of this historic and important American resource. This investment in our base business is a very important part of our business. Aside from providing a flow of oil, these efforts help us understand how oil reservoirs work—knowledge and technology that we can apply around the world so that our partners also can enhance their oil recovery from known resources.

Today in the United States, we have five major oil and natural gas projects under construction, with a total peak production capacity of 420,000 barrels per day of oil-equivalent. All these projects are expected to be in production by 2010.

At the same time that we are investing at the forefront of traditional energy such as oil and gas, we also are pursing advances in renewable technologies that are needed to help diversify supply and meet the challenges of tomorrow. To add to domestic energy resources, Chevron and many other companies are making investments in renewable energy. Since 2002, Chevron has spent more than $2 billion to develop renewables, alternatives and energy efficiency services. Between 2007 and 2009, our spending on renewable technologies and energy efficiency solutions will increase to $2.5 billion.

New technology to unlock the enormous potential of cellulosic ethanol is needed, and that's where companies such as Chevron are already taking steps to achieve progress. In 2006, we formed a biofuels business to advance technology and pursue commercial opportunities related to the production and distribution of ethanol and biodiesel in the United States. We recently announced a joint venture with Weyerhaeuser Corporation to pursue the research necessary to commercialize production of biofuels from nonfood sources. Catchlight Energy will work to develop technology that will lead to commercial biofuels production.

And more research is needed. We have strategic biofuels alliances with Georgia Tech, UC Davis, Texas A&M, the U.S. Department of Energy's National Renewable Energy Lab and the Colorado Center for Biorefining and Biofuels. Chevron was selected by the U.S Department of Energy to lead a consortium that has built five prototype hydrogen stations across the United States. We also are participating with AC Transit in the San Francisco Bay Area (California) on a zero-emission hydrogen bus project.

We are also investing in our refineries to continue to improve our ability to supply the products U.S. consumers need. At present, we are working on major projects at each of our big three U.S. refineries. Our U.S. downstream capital spending in 2008 will be $2.3 billion. Since 2002, we have invested $5.2 billion, which has resulted in additional supplies of more than 1 million gallons of transportation fuel production per day. We also are investing in refineries outside the United States, such as Pembroke, Wales, which can produce gasoline to meet U.S. and California specifications.

However, our investments in refining are sensitive to market forces, market direction and local permitting decisions. Government policies—such as the recently passed energy bill with its very ambitious program for renewable fuels—have created uncertainty over how much additional U.S. refining capacity may be needed to meet future U.S. demand. We have recently canceled work on a major refinery expansion project, due in part to that uncertainty.

Chevron is taking aggressive steps to increase energy efficiency

The energy challenges we face, globally or in the United States, cannot be met by addressing only the supply side. It is also important for all of us to realize that the most readily accessible source of new energy is conservation and efficiency. At Chevron, we embrace conservation as an important business strategy, and we are in our 17th year of reducing our own energy intensity. Since 1992, we have increased energy efficiency at Chevron by 27 percent.

And through Chevron Energy Solutions (CES), we are delivering energy efficiency projects that benefit federal, state and local governments; the public; and the environment. CES has completed over 800 projects involving energy efficiency and renewable power in the United States. These projects have accounted for over $1 billion in energy and operational savings, with a nearly 30 percent savings on average per project.

Chevron Energy Solutions has implemented energy efficiency, energy management and related energy improvements at government facilities across the United States. These projects include U.S. military bases such as: Beale Air Force Base, California; Department of the Navy, Marine Corps Logistics Base, Georgia; Department of the Army, Picatinny Arsenal, New Jersey; and the Department of the Army, Corpus Christi Army Depot, Texas. CES also has developed energy efficiency, solar power and clean energy projects for the U.S. Postal Service, including its Processing and Distribution Center in Oakland, California, and Mail Processing Facility in San Francisco, California. Another California solar project at Contra Costa Community College near San Francisco is the largest of its kind at an institution for higher learning in North America. The project will generate 3.2 megawatts of solar power and will save the college $70 million in energy costs over the next 25 years.

The National Petroleum Council Study: Urgent action is needed

The committee has asked what we recommend both industry and Congress can do to help consumers address the challenges from high-energy prices. There is no single or short-term solution to satisfy the world's growing appetite for energy—or to prevent the United States from being affected by the global energy dynamic.

We need a *range* of realistic solutions, and we need them at scale.

We literally need all the energy we can develop. This includes oil, natural gas, coal and nuclear power. It also includes renewables. And, just as important, it includes energy efficiency. The U.S. Energy Information Agency forecasts that over the next 25 years oil, coal and natural gas will provide roughly the same 86 percent of the world's total energy mix as they do today, and renewables will be an important component in our energy mix. The energy industry and other parties are making investments in all these areas, and it is important that they continue. All are needed to provide important additions to our energy supply portfolio. And all will play an important role in meeting increased energy demand. We believe it is not productive to impose additional punitive taxes on companies such as Chevron at a time when investments are needed in all forms of energy to meet growing demands at home and abroad.

At a time when more supply is needed, the United States has been reluctant to access some of its own resources. Chevron and others have been talking about the constrained supply-demand dynamic for the last several years, urging greater access to U.S. resources, onshore and offshore—especially given the time it takes for projects to come onstream. Instead, we have been increasing our demand on exporting countries because of policy decisions made here at home. Any serious measures toward energy security must seek to reverse this equation. As the world's largest consumer of energy, actions we ask of other producers must be matched at home.

Energy underpins every aspect of our society and our growing economy. The scale and breadth of the U.S. energy system is unsurpassed in the world, as is our energy demand. A sustained, reliable supply is essential, and that is achieved by bolstering supplies and moderating demand. The Energy Independence and Security Act of 2007 had important measures to moderate demand. However, it missed taking the additional step we believe is also urgently needed— improved access to off-limits oil and natural gas resources that we will need 10, 20 and 30 years from now.

Last summer, the National Petroleum Council (NPC) issued a sobering study called "Facing the Hard Truths About Energy," which outlines a comprehensive, integrated approach to U.S. energy security. The NPC study is a broad-based consensus effort representing the views of an impressive range of experts and stakeholders. Input was sought from more than 1,000 other stakeholders, in the U.S. and abroad; there were 350 participants with backgrounds in all aspects of energy including efficiency, economics, geopolitics and environment; 65 percent of participants were from outside the oil and gas industry, including nongovernmental organizations, academia, government, environmental and financial.

The NPC study highlights the need for an integrated national strategy given accumulating risks to the supply of reliable, affordable energy. The study highlights a number of "hard truths":

- Coal, oil, and natural gas will remain indispensable to meeting total projected energy demand growth.

- The world is not running out of energy resources, but there are accumulating risks to continuing expansion of oil and natural gas production from the conventional sources relied upon historically. These risks create significant challenges to meeting projected energy demand.

- To mitigate these risks, expansion of all economic energy sources will be required, including coal, nuclear, renewables, and unconventional oil and natural gas. Each of these sources faces significant challenges—including safety, environmental, political, or economic hurdles—and imposes infrastructure requirements for development and delivery.

- "Energy independence" should not be confused with strengthening energy security. The concept of energy independence is not realistic in the foreseeable future, whereas, U.S. energy security can be enhanced by moderating demand, expanding and diversifying domestic energy supplies, and strengthening global energy trade and investment. There can be no U.S. energy security without global energy security.

- A majority of the U.S. energy sector workforce, including skilled scientists and engineers, is eligible to retire within the next decade. The workforce must be replenished and trained.

- Policies aimed at curbing CO_2 emissions will alter the energy mix, increase energy-related costs and require reductions in demand growth.

The NPC study sets forth five core strategies to assist markets in meeting the energy challenges to 2030 and beyond. The United States must:

1. Moderate the growing demand for energy by increasing efficiency of transportation, residential, commercial and industrial uses.
2. Expand and diversify production from clean coal, nuclear, biomass, other renewables, and unconventional oil and natural gas; moderate the decline of conventional oil and natural gas production; and increase access for development of new resources.
3. Integrate energy policy into trade, economic, environmental, security, foreign policies; strengthen global energy trade and investment; and broaden dialogue with both producing and consuming nations to improve global energy security.
4. Enhance science and engineering capabilities and create long-term opportunities for research and development in all phases of the energy supply and demand system.
5. Develop the legal framework to enable carbon capture and sequestration (CCS). In addition, as policymakers consider options to reduce CO_2 emissions, provide an effective global framework for carbon management, including establishment of a transparent, predictable, economywide cost for CO_2 emissions.

The study further recommended that markets should be relied upon wherever possible to produce efficient solutions. Where markets need to be bolstered, policies should be implemented with care and consideration of possible unintended consequences.

The study is a catalyst for action. And action is needed now on all of the recommendations.

Changing our conventional wisdom on energy

Mr. Chairman, you asked me to address the issue of what measures can be taken to help the consumer deal with these rising energy prices and promote the use of alternatives. Let me reiterate that the NPC study has given us sound, sensible and achievable solutions. To successfully implement these recommendations we need to change our conventional wisdom about energy development and its use.

First, we need to value energy as a precious resource. Energy efficiency is the most immediate and important action that each of us can take to contribute to rising energy prices. The United States must become a nation of energy savers. In short we need a "Made in America" solution enabled by everything from human ingenuity, to "smart" buildings, to advanced vehicles and transportation systems. Increased energy efficiency and conservation will help reduce demand for energy and will reduce pressures on the system. Markets are indicating U.S. consumers are already taking action. You and your committee have a critical role to play to engage the U.S. public and put the United States at the forefront of responsible energy use.

Second, I would urge you to be sensitive to the issue of scale and timeframe. I hope that I have been able to demonstrate Chevron's commitment to the development of alternative sources of energy. This is an ambitious undertaking and one that we are embracing. But the scale of the energy system means that despite our combined efforts, renewables will meet less than 10 percent of demand in 2030, according to EIA estimates. We must continue to bring traditional energy supplies to market, even as we are developing alternatives sources of energy.

Third, on the supply side, we need your help to open up the 85 percent of the Outer Continental Shelf that is now off limits to environmentally responsible oil and gas exploration and development. We cannot expect other countries to expand their resource development to meet America's needs when our government limits development at home.

Finally, I would encourage careful evaluation of policies that can lead to unintended consequences and create inefficiencies in the gasoline supply system. Today we have 17 "boutique" fuel requirements across the country, requiring us to blend unique gasoline products for different states and different localities. More requirements on fuels are being added through renewable fuel mandates and proposed climate policies. For example, we are under a mandate to include rising levels of corn-based ethanol in our gasoline products and, over time, add significant quantities of celluosic ethanol. At the same time that we are accommodating these new mandates, policymakers have proposed legislation to reduce greenhouse gas emissions that again is focused very heavily on the transportation fuels sector. We urge you and your colleagues to reflect on how to advance these important national policies without inadvertently disrupting our ability to provide the gasoline and transportation fuels that the United States needs at prices that are affordable. Rationalization of these multiple requirements will create greater efficiencies in the fuel supply system.

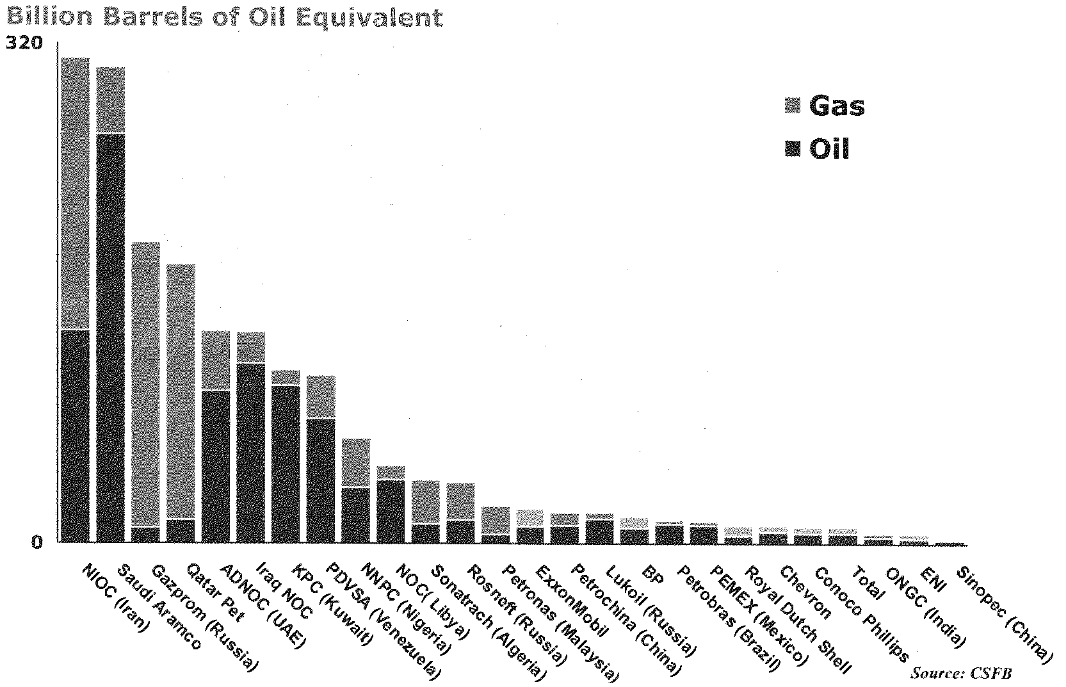
How we as a country deal with our energy future is nothing less than an urgent matter of our energy and economic security. Energy is vital to our nation's economic health. As such, a reliable, efficient and affordable energy supply system is a policy imperative. Realistic solutions must balance economic, environmental and security goals. Ultimately, polices should recognize the *inter*dependence of the United States within the global energy system, while at the same time capitalizing on our country's own extensive energy endowment. These are not insignificant challenges, and they will require leadership and collaboration. We look forward to working with you to address these challenges.

Chevron will continue to do its part.

Thank you.

Chart 1:
National Oil and Russian Companies Control 94 Percent of World's Reserves

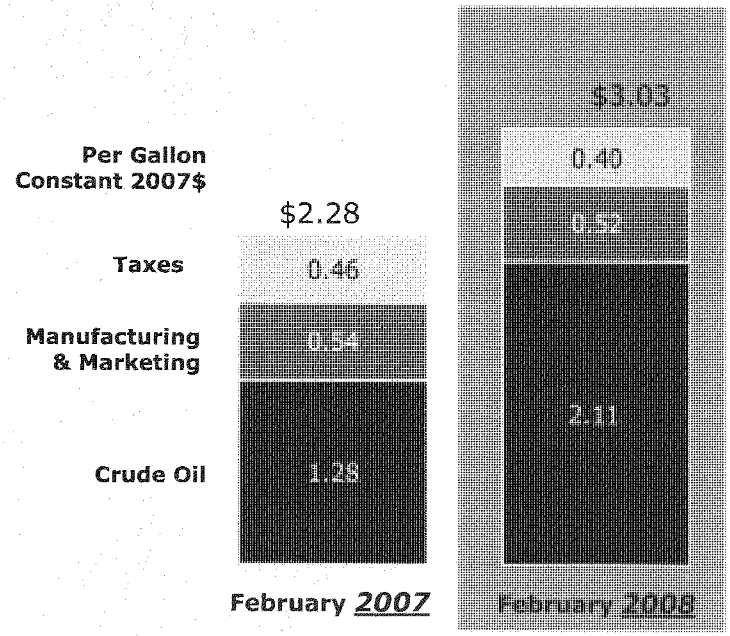
Chevron



Source: CSFB

Chart 2:

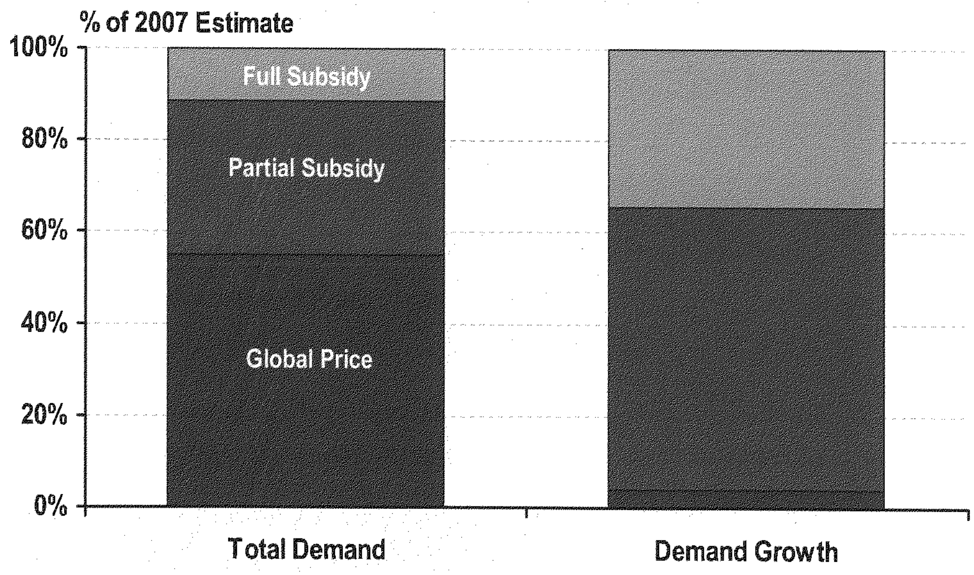
What We Pay - Gallon of Regular Gasoline



Sources: U.S. EIA/DOE Gasoline Fuel Update

Chart 3: Government Subsidies Artificially Support Demand Growth

Oil & Product Growth Occuring in Subsidized Areas



Source Data: IEA, PIRA

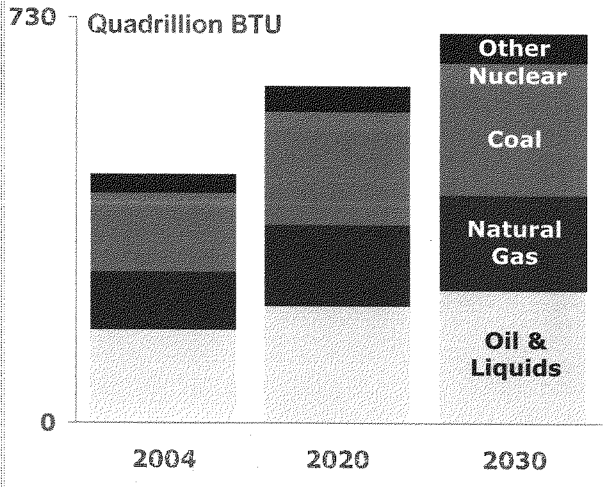
Chart 4:

World Energy Demand Continued Growth

Fuel Mix

- Relative percentages don't change
- Hydrocarbons make up 86% of the fuel mix
- Oil remains the predominant fuel at nearly 34%
- Renewable growth rates are high, but small in absolute terms

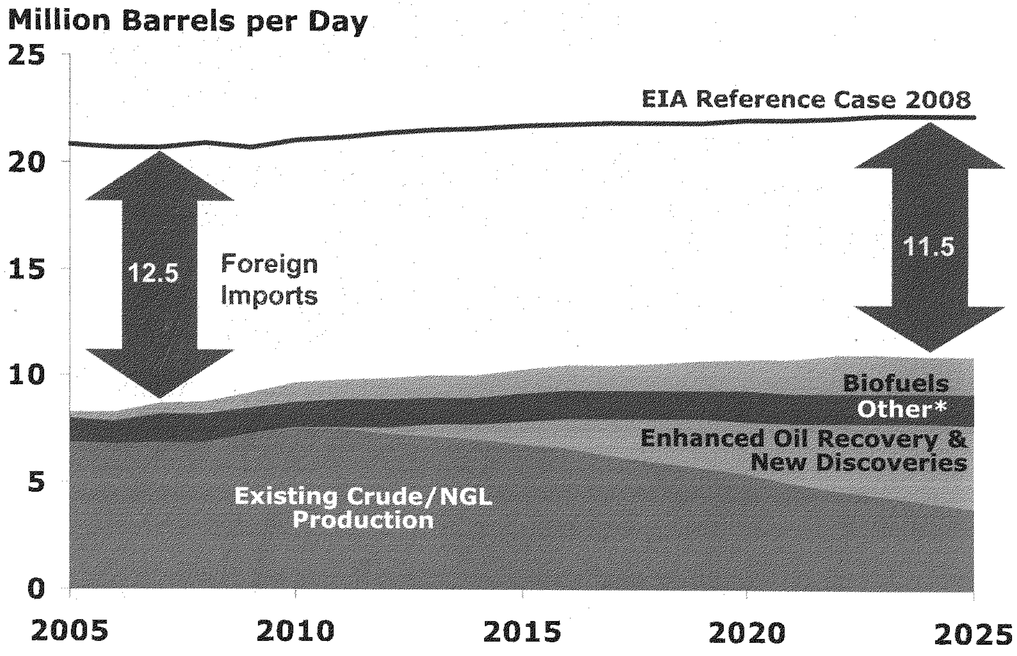
Global Energy Demand



Source Data: EIA/DOE International Energy Outlook 2007

Chart 5:
U.S. Domestic Oil Supply & Demand

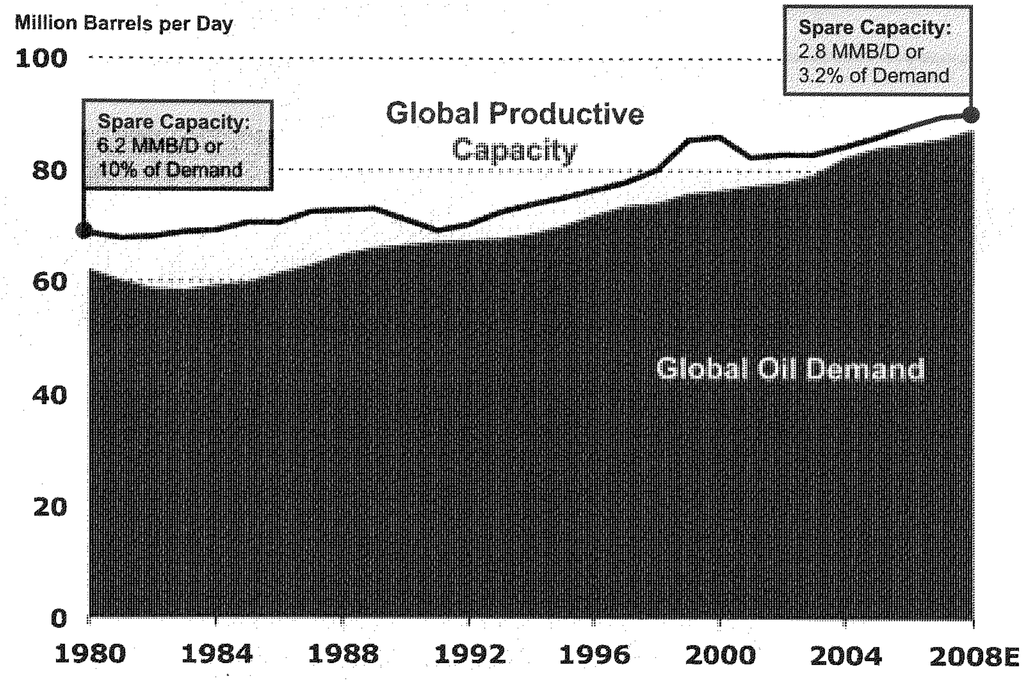
Includes Impact of EISA 2007



* Other includes refining process gains and other liquids.

Source: Woodmac & DOE/EIA Annual Energy Outlook Report 2008

Chart 6:
Spare Capacity Relative to Global Oil Demand

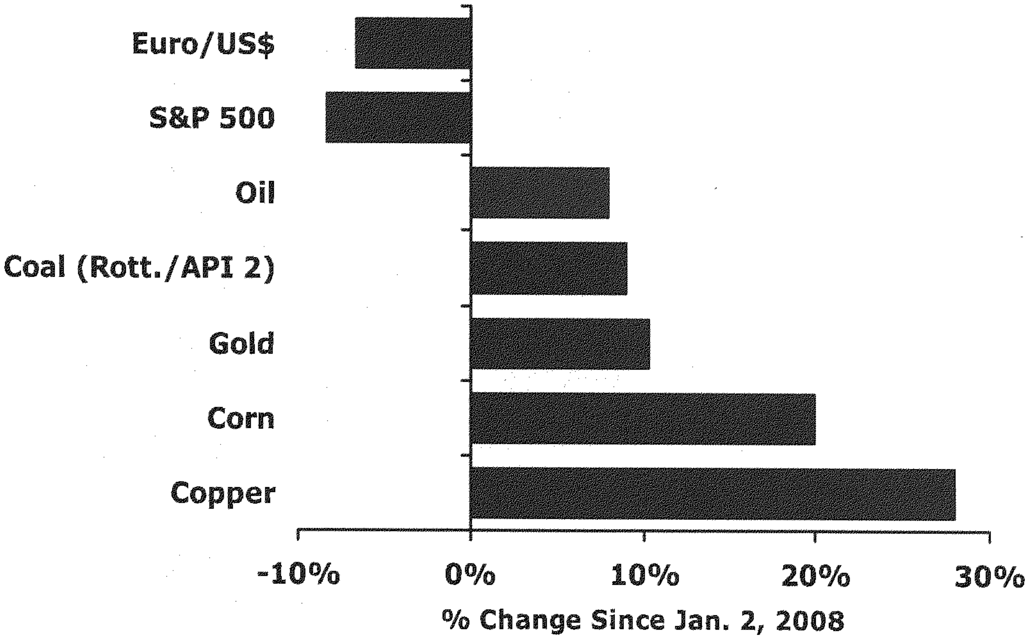


Spare Capacity:
6.2 MMB/D or
10% of Demand

Spare Capacity:
2.8 MMB/D or
3.2% of Demand

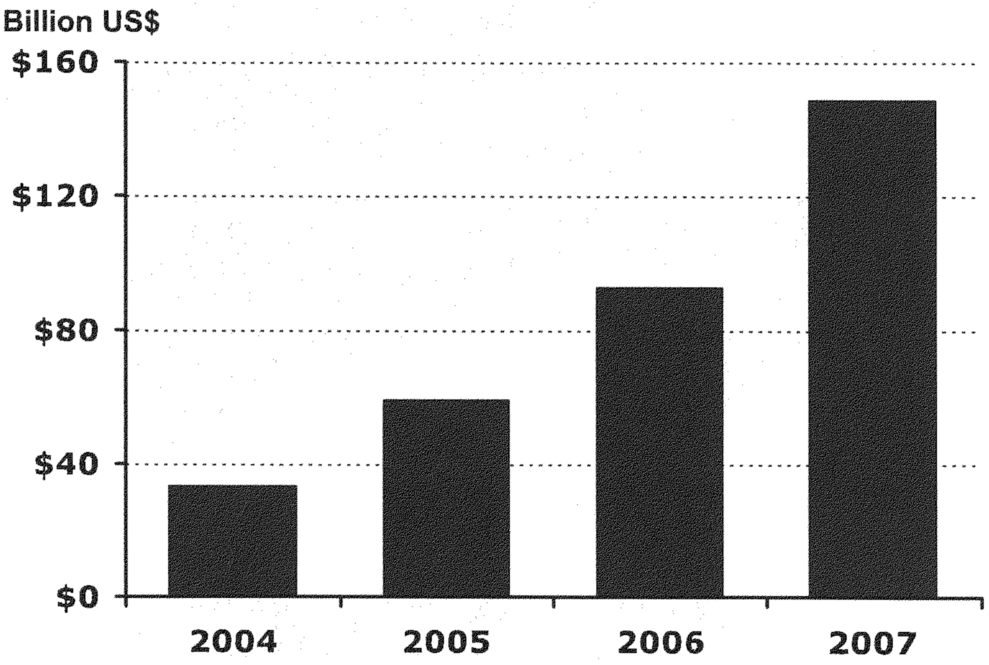
Source: IEA Monthly Oil Market Report

Chart 7:
Oil Prices have Risen Less Relative to Other Commodities



Source: Platt's Data as of Close on March 27, 2008

Chart 8:
Global Investment in Renewable & Alternative Energy*

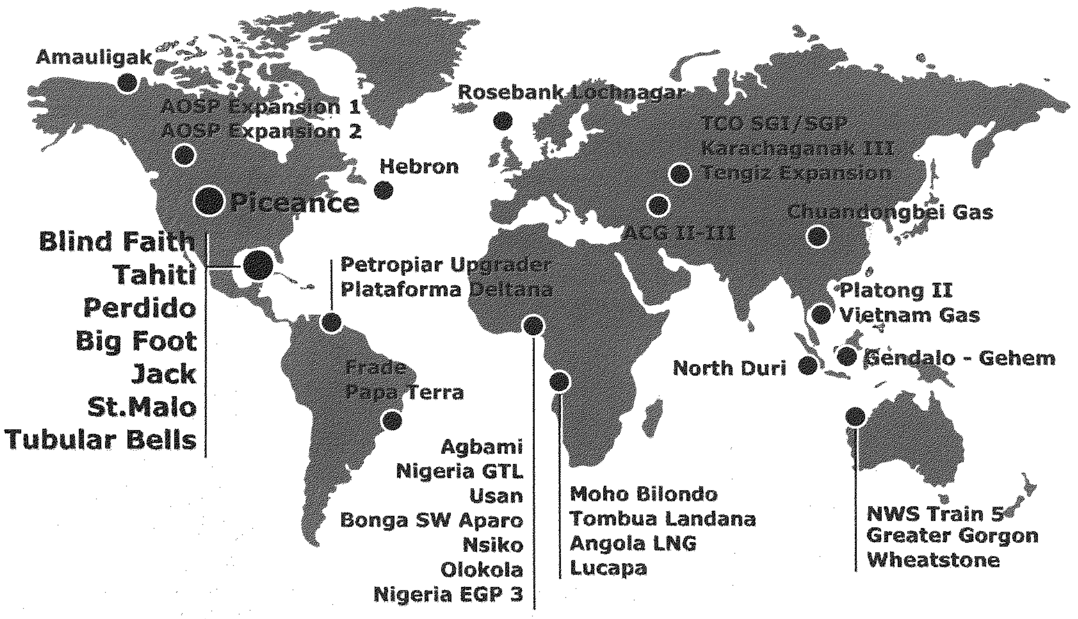


*Excludes M&A and Buyout Activity

Source: New Energy Finance, February 28, 2008

Chart 9:

Chevron's Portfolio of Upstream Projects



All projects shown are >$1B Chevron share.
Projects are in various stages of evaluation, design, construction or production.

The CHAIRMAN. Thank you, Mr. Robertson.

Our next witness is John Lowe. He is the Executive Vice President of ConocoPhillips. Over the last eight years he has held the multiple senior level positions with that company.

We welcome you sir. Whenever you are ready, please begin.

STATEMENT OF JOHN LOWE

Mr. LOWE. Thank you.

Good afternoon, Mr. Chairman. We appreciate the opportunity to come before the Committee to discuss our alternative fuels investments, as well as our investments to meet current energy needs.

ConocoPhillips favors developing all forms of energy, conventional, renewable, and alternative. However, we recognize that even with aggressive implementation of alternative energy, most sources estimate that fossil fuels must still supply two-thirds of world energy in 2030. We cannot attain an alternative energy future in a few short decades. Global energy demand is too high. Technological development and infrastructure construction take too long, and the cost would be too great.

This makes it essential that we build the political will to utilize our fossil fuel resources. We must also develop the ability to use them in cleaner forms, and we must disavow the misconception that alternative sources can quickly and easily assume the energy burden.

ConocoPhillips is already preparing for the future. Our reinvestments into our business continue exceeding our income. We earned $12 billion in 2007, but reinvested $13 billion, and we have over $15 billion in investments planned for 2008.

In North America, we are spending billions of dollars to expand supplies by developing the Canadian oil sands and building infrastructure to transport the oil to the U.S. In pursuit of natural gas, we are conducting major drilling programs and building pipelines in two LEG re-gas terminals.

Downstream we are increasing our refining capacity and ability to produce cleaner fuels.

You have also asked us to describe our efforts in renewable and alternative energy. Although these are currently not part of our core businesses, ethanol represents five percent of our U.S. gasoline volumes, making us one of the nation's largest ethanol blenders and users.

We are test marketing E85 and biodiesel. We have produced renewable diesel fuel. We are working to develop biofuels from agricultural waste. We are funding university research into the next generation of renewable fuels like cellulosic ethanol.

We are evaluating opportunities to invest in solar, wind and geothermal power. To make electric vehicles more practical, we are developing better materials for lithium ion batteries and to transform coal and petroleum coke into clean burning synthetic natural gas, we have developed proprietary technology and have two multi-billion dollar projects planned.

This Subcommittee is also charged with addressing climate change. ConocoPhillips favors congressional enactment of a mandatory framework to reduce carbon emissions, and we are actively researching potential carbon capture and storage. These efforts show what can be achieved by the industry's technical, financial, and human resources.

Our capabilities must not be undermined by punitive tax measures or counterproductive policies like those that threaten our coventure with Tyson Foods. Two years ago we formed a unique relationship with Tyson to develop a new technology to produce renewable diesel from byproduct animal fats. Unlike most biofuels, our product can be transported by pipeline.

Congress enacted an incentive for the feedstock, but the House is attempting to deny us equal treatment in utilizing this incentive, which is afforded to all other biodiesels. This would make our technology uncompetitive.

If Congress intends to encourage meaningful alternative fuels development, it is critical that all related tax policies and mandates be feedstock and technology neutral, and that R&D efforts not be undermined. The market should decide which technologies go forward.

Hopefully, government and industry can move beyond today's all too often adversarial relationship. There is much we can do together to increase supplies, encourage efficiency, develop alternatives, and address climate change. But have no doubt. The U.S. is engaged in a global race. Other countries are working cooperatively with their energy industries to secure new supplies. Unless our domestic companies are allowed to compete on level ground, we run the risk of marginalizing U.S. oil and gas industry and ultimately undermining U.S. energy supply.

Mr. Chairman, this concludes my statement. Thank you.

[The statement of Mr. Lowe follows:]

Testimony of John E. Lowe

Executive Vice President, Exploration and Production

ConocoPhillips

Before the

Select Committee on Energy Independence and Global Warming

U.S. House of Representatives

On

Tuesday, April 1, 2008

Introduction

Good morning, Mr. Chairman and Members of the Select Committee on Energy Independence and Global Warming. My name is John Lowe, and I am executive vice president of Exploration and Production for ConocoPhillips. In that capacity, I am responsible for worldwide oil and natural gas exploration, development and production for the company.

ConocoPhillips appreciates the invitation to testify about the present energy situation facing the United States and the world, as well as our activities to encourage increased supplies of alternative and renewable energy. We share your and the American public's concerns about high consumer energy prices and welcome the opportunity to discuss our own efforts to develop new energy sources that will improve the nation's energy security, as well as what we believe the government should do to facilitate the process.

Let me begin by briefly describing ConocoPhillips. We are an international, integrated energy company, headquartered in Houston, Texas and operating in nearly 40 countries. Among U.S.-based companies, we are the third-largest integrated energy company based on market capitalization, the second largest domestic refiner, and a leading natural gas producer. In 2007, we had annualized revenues of $187 billion, assets of $178 billion and approximately 32,600 employees at year-end.

As you requested, my testimony here today will address the following subjects:

- ConocoPhillips' activities in alternative and unconventional fuels,
- ConocoPhillips' activities to increase U.S. conventional oil and gas supply,
- Energy industry trends, and
- The path to a sound energy policy.

However, before I get to these topics I would like to discuss the need for cooperation between government and industry in forging solutions to our energy challenges.

Need for Cooperation Between Government and Industry

The United States faces some daunting energy challenges – improving the security and affordability of energy supplies, while also reducing the environmental footprint of the nation's energy use, including reducing greenhouse gas emissions. Responding effectively to these challenges will require unprecedented cooperation between government and industry. ConocoPhillips is eager to do our part on both fronts. We will describe today the substantial investments we are making to develop new energy supplies and our support of mandatory regulation of carbon. We believe that a regulatory framework and carbon avoidance price is needed to allow our company and others to make investments in improving efficiency, in developing low-carbon energy sources and in capturing and storing carbon dioxide from fossil fuels. In support of this belief, we joined the U.S. Climate Action Partnership to call upon government leaders to enact a workable architecture for a mandatory national carbon cap and trade program with international ties.

While we are optimistic about what industry and government could accomplish collaboratively, we must share our frustration with the present state of affairs. We are hopeful that, through dialogues such as today's, our industry and the government can forge a better working relationship that will be essential in enabling America to address its energy needs, as other countries around the world are doing. We acknowledge that the industry has not done a good job of educating the public or Congress about our business in the past. Because of this oversight on our part, many policies emanating from Capitol Hill do not reflect how global energy markets actually function, and therefore will not improve the situation. These shortcomings must change so that together, we may progress toward improving U.S. energy supply security on behalf of consumers. For our part, ConocoPhillips has stepped up our public outreach efforts on energy issues in recent years. For example, last year our executives held "conversations on energy" with community leaders in 35 cities across the United States to discuss energy issues and solutions.

Unfortunately, at a time when the world needs more energy, rising worldwide resource nationalism in other countries and limited domestic access to resources here at home are impeding our industry's crucial efforts to replace current production with new reserves. In other countries, governments work closely with their domestic energy industry to assure access to resources and build critical energy infrastructure.

We must point out that as our nation develops policies to increase supplies of renewable and alternative energy supplies, we must not overlook the vital need to also encourage the development of conventional supplies of oil and natural gas. To focus strictly on one and not on both, is certain to create supply problems in the near future. As Congress periodically debated the architecture of a national energy policy, the industry has consistently stressed the need for more resource access. Gaining this access is, in fact, critical to lowering energy prices. Yet, domestic access restrictions are increasing. To illustrate this point, during the most recent energy bill debate, the House of Representatives voted to ban drilling in Colorado's Roan Plateau Basin, a potentially prolific natural gas producing area, further decreasing the areas of the U.S. accessible to resource development. Development of domestic natural gas offers the dual benefits of improving U.S. energy security and lowering carbon dioxide emissions. We cannot see a viable policy solution to either challenge without an increased role for domestic natural gas.

Additionally, we have had many discussions on Capitol Hill in which our industry was urged to build new domestic refineries or expand existing facilities. Yet today, we face state and local government roadblocks that often delay planned refinery expansions, along with an uncertain regulatory climate, which increases the cost of producing more clean-fuel products and of processing the more difficult crude oils that increasingly constitute available supplies. In cases where infrastructure is clearly needed to serve the national interest, Congress should expedite federal and state permitting processes to ensure there is a balance between federal, state and local, and special interests. We also find that investors are confused about whether the industry's efforts to expand refining capacity actually conflict with the many other Congressional policies calling for reduced dependence on oil.

ConocoPhillips strongly favors rapid development of alternative sources, but there are many challenges that must be overcome before these alternatives are commercially viable. For example, the National Petroleum Council recently reported that potential obstacles to wider use of renewable fuels include the need for "expanding rail, waterway, and pipeline transportation; scaling up ethanol production plants and distribution systems; developing successful cellulosic ethanol conversion technology; and maximizing the potential of arable land."[1] With potential advances in technology and infrastructure improvements, these obstacles can be overcome, but we must realize that alternatives cannot be developed overnight and that our dependence on conventional resources will continue into the foreseeable future. Overestimating how quickly the United States can transition to new fuels will likely lead to inadequate development of conventional supplies and higher prices at the pump.

Most energy demand projections indicate that even with rapid penetration of alternative-energy technologies, accompanied by substantial reductions in carbon dioxide emissions, fossil fuels must still supply at least two-thirds of global energy by 2030.[2] Indeed, there is an apparent misunderstanding of the enormous scale of fossil-fuel use – for example, the world currently consumes 86 million barrels per day of oil – or 40,000 gallons per second. There is also a lack of understanding of the enormous scale of existing infrastructure or the ongoing investment required merely to maintain existing production. For example, the United States has 200,000 miles of oil pipelines and 280,000 miles of natural gas pipelines that required a century of construction.[3] Oil and natural gas must serve as important bridge fuels as we move toward alternative sources. If the United States is to improve its energy security, Congress must ensure that the nation has sufficient conventional oil and gas supplies, even as it works to develop alternative energy supplies. Figure 1 below shows how much oil production will need to be added to replace the decline in existing conventional oil production and expand supplies. It will take unprecedented investment to achieve the production levels required to satisfy global oil demand. In fact, the International Energy Agency estimates that through 2030, nearly $10 trillion of investments in oil and natural gas exploration and production, refining, transportation and infrastructure will be required, averaging about $400 billion annually.[4]

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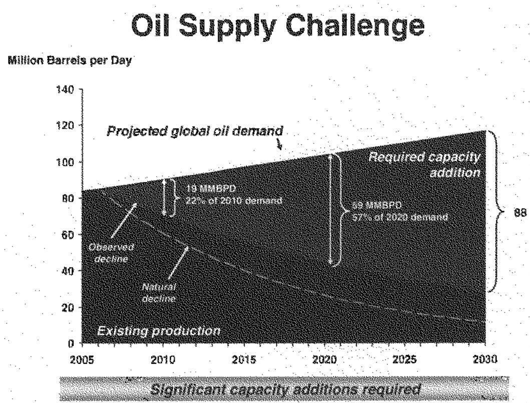
[1] National Petroleum Council, "Facing the Hard Truths about Energy," 2007, page 21
[2] International Energy Agency, "World Energy Outlook 2007"
[3] National Petroleum Council, "Facing the Hard Truths about Energy," 2007, page 12

Figure 1



Source: Based on IEA World Energy Outlook 2007
Natural decline forecast at 8% rate
Observed decline forecast at 4.5% rate requires substantial investment

The Committee has asked us to address the question of what ConocoPhillips is doing to develop alternative fuels. We believe that it is critical for the nation and our company to diversify into alternative energy sources and support efforts to that end. Over two years ago, Tyson Foods and ConocoPhillips began discussions that led to an unusual relationship between the two companies. We developed a process that married Tyson's technologies in dealing with by-product animal fats and greases with our refining know-how, to produce a clean, renewable diesel fuel that, unlike other biodiesel fuels, can be transported via pipelines. We were excited about this new venture and have been told by many lawmakers it represents the very kind of partnership and innovation that is needed to advance alternatives and reduce dependence on imported oil. Yet today, we find that partnership very much in question due to legislation passed in the House that denies us the same blending tax treatment provided to all other renewable and biodiesel producers. We cannot compete in a market where a few competitors are singled out for discriminatory treatment. Policies that encourage alternative fuel growth must be technology and feedstock neutral. To do otherwise will surely limit the growth of alternative fuels in this country.

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[4] International Energy Agency, "World Energy Outlook 2007," page 95

We are also concerned that recent Congressional tax proposals would reduce funds available to invest in developing new energy supplies and impede the ability of American companies to compete in the global marketplace for resources. This would further tighten the energy market – the opposite of Congress' intent. This nation already learned this lesson from the windfall profits tax imposed on the domestic oil industry between 1980 and 1988. According to the Congressional Research Service, this tax reduced domestic oil production by as much as 6 percent and increased oil imports by as much as 16 percent.[5]

Some tax proposals would target only a handful of the integrated major energy companies – a patently unfair approach that does not acknowledge that these companies already pay their fair share of taxes. In a recent survey of 80 diverse American companies, ConocoPhillips' effective tax rate between 2004 and 2006 of 43.6 percent was the highest, about 14 percent higher than the average.[6] Income taxes paid by domestic energy producers have already increased by 460 percent between 2002 and 2005.[7] Income taxes are only one of the ways we contribute to government revenues. We also pay royalties, production and excise taxes, and lease bonuses, which are paid whether you discover hydrocarbons or have a dry hole. When you take all these other forms of government payment into account, our effective tax rates are much higher. For example, our incremental fiscal government take rate in Alaska is about 85 percent at current prices.

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[5] U.S. Congressional Research Service, "The Windfall Profits Tax on Crude Oil: Overview of the Issues," September 12, 1990, page 2

[6] Martin A. Sullivan, "Reported Corporate Effective Tax Rates Down Since Late 1990s," Tax Notes, February 25, 2008

[7] U.S. Department of Energy, Energy Information Administration, "Performance Profiles of Major Energy Producers 2006," Table B12 ($14.5 billion in 2002 to $81.5 billion in 2006)

We must change the current adversarial relationship between industry and government in order to accomplish either goal of improving energy security or reducing the risk of climate change. We have some suggestions on policies that could be enacted to help achieve these goals and will share them later in this testimony.

ConocoPhillips' Activities in Alternative and Unconventional Fuels

Renewable energy

ConocoPhillips is already a large blender of conventional ethanol in the United States. As the nation's second-largest refiner and fuels producer, we are thus a large blender of ethanol into fuels. In 2007, our marketers in the United States sold about 425 million gallons of ethanol, equivalent to a nationwide blend rate of 4.7 percent. Additionally, we are rapidly expanding our U.S. ethanol blending capabilities. We have expanded capability for blending ethanol to 95 terminals this year and are evaluating additional expansions. We are selectively adding biodiesel blending capabilities, although this fuel is currently priced higher than petroleum-based diesel fuel, and the economics of blending are challenged.

We are test marketing unbranded E-85 under our branded canopy in a number of states with over 2,500 potential sites, provided the marketer meets certain image, safety and fuel-quality guidelines. Results from our test are pending; but industry data has shown that the consumer response to E-85 to date has not been very good. Many retailers who have installed E-85 dispensers report insufficient consumer demand to justify the expense of the conversion. The problem is that there aren't enough vehicles with flexible fuel capability today (only about 3 percent of the U.S. passenger fleet), and consumers who own flexible fuel vehicles are often unaware of it. In addition, consumers are concerned about the roughly 25-percent reduction in gas mileage using E-85 versus conventional gasoline.

ConocoPhillips is also test marketing biodiesel, allowing under-the-canopy sales of unbranded B11 in Illinois and of branded B5 in many farm states, again provided that the marketer meets specific image, safety and fuel-quality guidelines. Over 800 branded sites could potentially pilot market biodiesel in five states.

The company is also engaged in development and production of new biofuels that have a better environmental footprint than existing sources. We currently produce renewable diesel fuel at our Whitegate refinery in Ireland using vegetable oils as a feedstock and are test manufacturing the process at our Borger refinery in Texas as part of our arrangement with Tyson Foods to utilize by-product animal fat as a feedstock. Our process produces diesel fuel that does not have the same performance and transportation issues as biodiesel. The technology is performing well, but the economics are threatened by rising raw material costs and the prospective loss of the previously-mentioned federal tax credits that are available to competing biomass-based diesel fuels. We are prepared to spend $50 million this year to expand production if the technology is economically viable.

ConocoPhillips conducts or funds internal and external research on new biomass fuels and has a joint development agreement with Archer Daniels Midland to develop fuels from agricultural waste. This effort could enable biomass to become a refinery feedstock that yields market-compatible fuels. We also have a major relationship with Iowa State University to research all phases of biofuels. In addition to funding new advanced biomass pathways, our eight-year $22.5 million grant will fund research to understand and support environmental sustainability, crop improvement and production, harvesting and transportation and the impact of biofuels on economic policy and rural sociology. We are also a founding member of the Colorado Center for Biorefining and Biofuels, a cooperative research and educational center devoted to the conversion of biomass to fuels and other products.

Further, ConocoPhillips has created an internal group dedicated to evaluating opportunities to invest in solar, wind and geothermal projects. We have also committed

$350,000 to Virginia Tech University as the primary corporate sponsor of a solar-powered home that will showcase advanced residential solar and energy efficiency products. This home will be entered into a national competition in Washington, D.C. next year.

Alternative automotive technology

ConocoPhillips has participated in the FreedomCAR and Fuel Partnership with the U.S. Department of Energy, automobile manufacturers and other fuel providers since 2003. We have played a lead role in several committees and participate in four out of the five technical teams, including the teams for hydrogen production, storage and delivery.

We are also working to facilitate wider use of electric vehicles by developing high-performance materials for lithium-ion batteries, a critical component in these vehicles. Performance of the cathode and anode parts determines overall battery performance, and ConocoPhillips CPreme® graphites are the highest-performing anode materials currently available for lithium-ion batteries. We currently supply anode material in small lots, but are rapidly scaling up to meet growing transportation demand. Using the technology platform for the anode material, we are also developing high-performance cathode material to help reduce the cost of batteries, while meeting demanding automotive-industry performance standards. This product will soon be available for testing by battery manufacturers.

Gasification and combined heat and power

ConocoPhillips' E-Gas™ technology is a leading, commercially proven gasification technique. We are developing projects based on this technology and licensing it to others to utilize in producing synthetic natural gas, electrical power and a variety of chemicals. Syngas can replace increasingly expensive oil or natural gas-based fuels and feedstocks currently supplying manufacturing plants, and may thus help sustain their financial viability and employment base. Further, a coal-to-synthetic natural gas plant with carbon capture and storage can feed a conventional gas-based power plant, yielding about half the carbon dioxide emissions of a conventional coal-based power plant. In addition, integrated gasification combined cycle (IGCC) power plants based on E-Gas™ technology offer an environmentally superior way to produce electrical power from domestic coal and petroleum coke resources.

Our two major E-Gas™ equity gasification projects could be on line by 2014, at total expected gross capital costs of up to $7 billion. One, a joint venture with Peabody Energy to develop a coal-to-substitute-natural-gas facility in Western Kentucky, would produce up to 70 billion cubic feet per year or 1.5 trillion cubic feet in 30 years – equivalent to a very large natural gas field. In the second, ConocoPhillips is developing a petroleum coke gasification project at our Sweeny refinery on the Texas Gulf Coast. It will utilize 5,000 tons per day of petroleum coke. Its location provides multiple options for product integration. The resulting carbon dioxide production of 10 million metric tons annually from these two projects could be utilized in enhanced oil recovery operations or sent to storage. Here again, we need government's help in establishing a conducive legal and regulatory framework to address carbon, capture and storage.

ConocoPhillips believes that wider use of combined heat and power facilities is an important part of the solution to conserve fuel and reduce carbon dioxide emissions. We operate about 2,000 megawatts of electricity generation capacity using this technology and have encouraged third parties to build such capability at four other ConocoPhillips facilities.

Heavy oil and unconventional oil and natural gas

ConocoPhillips is presently undertaking significant research to improve the recovery of heavy oil and unconventional oil, such as oil shale, and improve energy efficiency throughout the production, transportation and processing value chain. We are also undertaking research and development focused on reducing our environmental footprint in terms of greenhouse gas emissions, water and land use.

Other areas of focus for our research and development efforts include improving recovery of challenged natural gas and developing methods to commercially produce methane hydrates.

Carbon dioxide capture and storage and water usage

ConocoPhillips believes that development of carbon capture and storage (CCS) technology is essential, in that, it will improve the environmental acceptability of available fossil fuel resources. The company funds internal research as well as university research programs in the United States, Canada, Australia, Norway and the United Kingdom that are investigating CCS technology and how it can be customized to meet our industry's needs and the needs of our specific sites.

We are in the planning phases for selecting several possible CCS sites in the United States and other countries. To facilitate this effort, we have allocated personnel in the geosciences, reservoir engineering and other specialties to analyze seismic and engineering data to select the most appropriate sites and develop understanding of the basin containment mechanisms and optimum storage sizes.

ConocoPhillips is also engaged in a number of research projects with the U.S. Department of Energy (DOE). We are operator of a scientific test of potential carbon dioxide (CO_2) injection rates into the major coal formations of the San Juan Basin. We expect to soon receive DOE's authorization to commence drilling and injection. We are also actively engaged with two other DOE regional partnerships – WestCarb and the Midwest Geological Sequestration Consortium. We are a partner in the CO_2 Capture Project 2, a research consortium operated and funded by eight major energy companies, the European Union, Norway, and DOE. The consortium reviewed 250 research proposals and has focused on the most likely to succeed, conducting more than $60 million in research projects to develop understanding of surface capture, subsurface storage applications, and methods to monitor and verify storage. The program is working to make CCS more affordable, secure and technically viable. We are active at the executive board and scientific levels.

ConocoPhillips is also active in these international research consortia:

- CACHET – Partly funded by the European Union and 28 international members, this consortium focuses on capture technology.
- International Energy Agency (IEA) Greenhouse Gas R&D Programme – We are a funding member and serve on the board.
- CO_2CRC – The Cooperative Research Centre for Greenhouse Gas Technologies (Australia) is one of the world's leading collaborative research organizations focused on carbon dioxide capture and geological storage (geosequestration).
- CO_2ReMoVe (European Union) – This is a $20 million project for carbon dioxide monitoring technologies in the subsurface.

As for other carbon emissions reduction solutions, we understand the major point sources of emissions in our operations and have analyzed and ranked potential mitigation projects. Projects to improve energy efficiency and eliminate fugitive emissions are already underway. A cost for avoiding carbon is also considered in our evaluation of major new projects.

ConocoPhillips believes that reducing the footprint of energy production on water resources will help improve the sustainability of both conventional and alternative energy sources. We are measuring our freshwater usage and developing detailed water assessments of selected business units, bringing greater focus to water management as a fundamental component of business planning. We recently announced the establishment of the Qatar Water Sustainability Center, with the long-term vision that it will become a corporate center of excellence for water-related technologies. We have hired a world-class membrane expert to lead our technology development and application efforts at this center, which will be additive to technology work under way in our existing Oklahoma laboratories. In the North Sea, we have installed new treatment technologies to substantially reduce the hydrocarbon component of water discharged to the ocean. ConocoPhillips Canada is planning to recycle 95 percent of the water utilized in its steam-assisted gravity drainage for heavy oil in-situ operations.

Activities to Increase U.S. Conventional Oil and Gas Supply

Fossil fuels will continue to provide an important bridge to the time when alternative energy sources are available in significant quantities. This bridge is likely to be necessary for decades given the scale of the world's current energy consumption and the massive infrastructure investment and construction that would be needed to replace existing energy infrastructure. Thus, it is important that the energy industry retain the capability and opportunity to invest sufficient capital in economically attractive traditional oil and gas opportunities in order to continue meeting U.S. and global energy demand.

Upstream investment and exploration

ConocoPhillips has significant investments planned to develop oil and natural gas resources in North America. In 2008, we will spend more than $6 billion in North America, with two-thirds of that amount in the United States.

North America is a key exploration focus area for ConocoPhillips. We predominantly operate in large resource plays onshore and the deepwater trend in the Gulf of Mexico offshore. In the Arctic we have exploration acreage in the Chukchi Sea, Mackenzie Delta area and Canadian arctic islands. In fact, we are planning on spending more than $890 million this year alone for our high bids in Gulf of Mexico and Chukchi Sea lease sales.

We are also conducting considerable research and development to improve recovery rates from existing resources, which could add considerably to the resource base. For example, we are developing and deploying improved seismic acquisition, processing and interpretation techniques to increase recovery from existing assets – such as through improved well placement that accesses new resources that were previously difficult to image. Another example is our research into the next generation of improved/enhanced oil recovery techniques (e.g., nano-technology and enhanced water flooding). A third example is applying alternative techniques to facilitate cost-effective drilling in challenged resource plays, thus improving access and recovery. Among the techniques used are new mobile drilling rigs in the Barnett shale trend and horizontal wells in coal bed methane trends.

Heavy oil

The Canadian oil sands are projected to become an increasingly important source of oil for the United States, particularly considering recent declines in heavy oil production in Mexico, Venezuela and California. The Canadian oil sands are projected to approach 20 percent of U.S. oil supplies by 2020.[8]

ConocoPhillips has a leading land position in the Canadian Athabasca oil sands and is actively investing to produce this oil, and then transport it to the United States for processing at our refineries. We have access to over 15 billion barrels of net potential oil resources, and plans are in place to increase our net production to about 400,000 barrels per day over the next decade. In 2008 alone, we are spending $900 million in development capital on the Canadian oil sands.

ConocoPhillips is also spending significantly on technology to improve heavy oil output and reduce the resulting environmental and carbon footprint. For example, ConocoPhillips Canada is a member of the Integrated CO_2 Network, an industry and government consortium researching development of pipeline infrastructure to transport carbon dioxide from oil sands development sites to locations where it can be used in enhanced oil recovery, or potentially sequestered below ground. We have also invested in research and development projects that study alternate recovery technologies, which reduce both our energy requirements and carbon footprint.

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[8] Purvin and Gertz (18.5%)

ConocoPhillips also has a 50 percent interest in developing the 2,148-mile Keystone oil pipeline, which will transport additional Canadian crude oil to the United States. The pipeline will have an initial nominal capacity of 435,000 barrels per day in late 2009 and will be expanded to a nominal capacity of 590,000 barrels per day in late 2010.

We are working to expand the Wood River refinery (a 50 percent joint venture with EnCana) in Illinois to enable it to utilize additional volumes from the Canadian oil sands. This expansion will increase Wood River's crude inputs by 54,000 barrels per day and increase the yield of total clean-fuel refined products by 80,000 barrels per day. This proposed expansion has been delayed by a pending appeal of a permit that was previously granted for the project by the Illinois Environmental Protection Agency.

Natural gas

ConocoPhillips was the leading natural gas producer in the United States in 2007, producing about 2.3 billion cubic feet per day (or enough to fuel over 10 million homes in the United States). ConocoPhillips has a significant domestic natural gas resource base (about 12.6 trillion cubic feet of proved gas reserves), and is actively adding acreage in large resource plays and exploring for additional supplies. For example, we plan to drill more than 200 exploration wells onshore in North America during 2008.

We are also investing to improve our natural gas delivery capabilities. We have a 25 percent ownership position in the Rockies Express pipeline, which was recently built to move trapped Rockies natural gas to Midwest and East Coast markets. The pipeline's western segment is projected to reach Missouri shortly, and the eastern segment is projected to reach the Ohio terminus in January 2009, reaching full capacity at 1.8 billion cubic feet per day in June 2009. We also have invested in liquefied natural gas (LNG) regasification facilities on the Gulf Coast in order to provide a potential outlet for LNG supplies we are developing around the world.

Natural gas is an important bridge fuel to a low carbon world since it is the most greenhouse gas-friendly fossil fuel.

Arctic activities

ConocoPhillips is Alaska's largest oil and natural gas producer, with production of 300,000 barrels of oil equivalent per day in 2007.

Alaska holds significant stranded natural gas resources, which if connected to the lower 48 states, would increase commercially proven U.S. gas reserves by about 17 percent. ConocoPhillips has long urged progress on the proposed 4 billion cubic feet per day Alaska natural gas pipeline, and we applaud Congress for your bipartisan efforts in passing the needed "Enabling Legislation" to progress this project. We are moving forward on planning the pipeline and are continuing our dialogue to deliver a project acceptable to all stakeholders. In order for this project to advance, close cooperation between all resource owners, the State of Alaska and the Canadian and U.S. federal governments will ultimately be needed.

ConocoPhillips is also working with our partners, native groups and the Canadian federal government to move the 763-mile Mackenzie Delta gas pipeline project forward. The 1.2 billion cubic feet per day pipeline project would connect northern onshore gas fields with North American markets and provide consumers additional supplies of much needed natural gas.

Refining, marketing and transportation

In 2008, ConocoPhillips plans to invest $2.8 billion in our global refining, marketing and transportation operations. Of that amount, 74 percent will be invested in the United States and 69 percent will be invested in refining.

Over the next five years (2008-2012), we plan to invest $7.0 - $7.5 billion in our base refining, marketing and transportation business, with 80 percent of that spent on continued investments in reliability, safety, expansion of clean fuels production and emissions reduction. The other 20 percent of that spending will be for projects that provide an economic return, such as those intended to improve refinery yield and margin, enhance energy efficiency, reduce operating costs or enhance crude oil advantage or product flexibility. Ongoing capital requirements for safety and reliability and to meet all regulatory requirements are large, which makes it challenging for the refining industry to achieve attractive returns on capital.

We also plan to spend $6.5 - $7.0 billion over the next five years (2008-2012) on strategic investments, which are primarily refinery projects that increase crude capacity, clean product yields, or the ability to utilize low-cost crude supply.

We are targeting a 10 percent reduction in the energy intensity index of our U.S. refining system by 2012, as part of a voluntary commitment through the American Petroleum Institute to reduce carbon dioxide emissions in the U.S. refining sector. This reduction also makes good business sense because, as a large consumer of energy, the refining industry has been adversely impacted by higher energy prices in recent years.

Energy Industry Trends

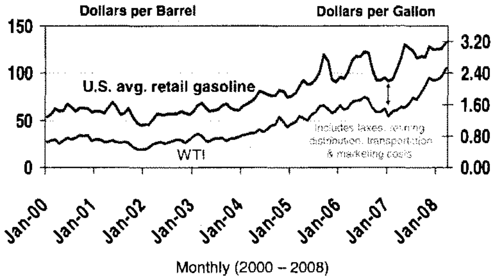
Global crude oil prices

We would like to share our views on why gasoline and diesel fuel prices have increased in the United States in recent years. Historical analysis shows that changes in crude oil prices explained about 97 percent of the variation in the pre-tax price of gasoline between

1918 and 2006.[9] Figure 2 below shows that gasoline prices have historically moved with crude oil prices, primarily because crude oil prices are the largest single cost component of refined products. According to the U.S. Department of Energy, in January 2008, crude prices constituted 68 percent of the retail price of a gallon of gasoline.[10]

Figure 2

Retail Gasoline & World Crude Oil Price



Source: U.S. Department of Energy
Conventional regular retail gasoline

Crude oil is a global commodity with prices determined by the interaction of thousands of buyers and sellers in physical as well as futures markets around the world. Prices set in this global market reflect both current and future expected supply and demand.

One of the biggest drivers of global oil prices has been sustained *global economic growth* since 2004, which led to stronger-than-expected energy demand growth. In fact, real growth in global gross domestic product between 2004 and 2007 of nearly 5 percent per year was about 40 percent higher than the average growth rate since 1980.[11] Due to this economic prosperity, between 2004 and 2007 oil demand grew by 2 percent per year, almost twice the rate experienced from 2000 to 2003. Nearly half of the demand growth since 2000 has been in developing Asian nations that have reached a highly energy-intensive stage of economic growth. In these nations, rising per-capita income also enables a larger proportion of the population to afford affluent lifestyles similar to those in the United States. Although responsible for only 12 percent of global oil demand growth since 2000, the United States, with just five percent of the world's population, still accounts for 24 percent of global oil demand.[12]

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[9] Carol Dahl, Colorado School of Mines, "What Goes Down Must Come Up; A Review of the Factors Behind Increasing Gasoline Prices, 1999-2006," April 2007

[10] U.S. Department of Energy, Energy Information Administration, "Gasoline and Diesel Fuel Update," March 10, 2008 based on January 2008 gasoline price ($3.04/gallon)

[11] International Monetary Fund, "Updated October 2007 World GDP Growth and PPP Weights," January 30, 2008 (4.7% average for 2004-2007 vs. 3.3% average from 1980-2007)

A second reason for high global crude oil prices is *constraints on expanding conventional supplies,* in particular, rising resource nationalism that limits access to resources for development. Figure 3 below shows that in the 1960s, 85 percent of global oil and natural gas reserves were available for direct development by international oil companies, versus only 7 percent today. In addition, rising competition for access to the resources that are open for development has enabled host governments to dictate fiscal terms that are so onerous that publicly traded oil companies cannot economically pursue them. Morgan Stanley estimates that the tax rates of major oil companies have increased from about 30 percent to 45 percent since 2000.[13] In some cases, governments change fiscal terms after investments have been made or increase taxes on existing production, even in mature producing areas in otherwise stable countries (Alaska in the United States, and the United Kingdom). Such actions can make it uneconomic to invest the capital required to slow decline rates in existing fields.

As mentioned earlier, resource access is also very limited in the United States, where an estimated 40 billion barrels of technically recoverable oil resources are either completely off limits or subject to significant lease restrictions. Similar restrictions apply to more than 250 trillion cubic feet of recoverable natural gas resources.[14]

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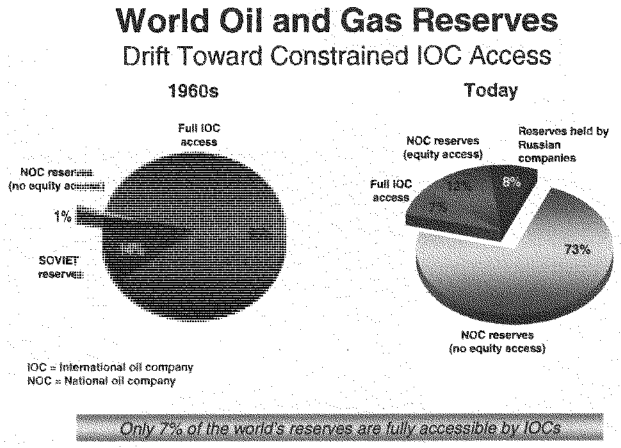
[12] International Energy Agency, Annual Statistical Supplement and Monthly Oil Market Report, March 11, 2008; United Nations for world population
[13] Morgan Stanley Research, "Integrated Oil," March 14, 2008, Exhibit 17, page 11
[14] National Petroleum Council, "Facing the Hard Truths about Energy," 2007, page 20

Figure 3



Source: PFC Energy, Oil & Gas Journal, BP Statistical Review 2007
Note: Excludes unconventional crude oil and bitumen reserves

Another constraint on supplies is rapid inflation in industry drilling and service costs. An upstream capital cost index, published by Cambridge Energy Research Associates, indicates that industry capital costs have approximately doubled since 2000,[15] reflecting higher costs for materials, equipment and personnel. Driving factors include higher industry activity and spending levels, as well as strong demand for materials, equipment and people in other sectors of the global economy. Industry costs are also pushed upward by limited resource access and depletion of existing lower-cost resources, which force the industry to develop higher-cost resources. These may be located in deeper water or more remote locations, or may be more unconventional in nature, requiring specialized development and refining techniques. It is important to recognize that inflation in capital and labor costs is also adversely impacting the economics of alternative energy sources.

Also pushing crude oil prices upward is the high *geopolitical supply risk* attributable to the world's low level of excess oil production capacity and the fact that in several key oil-producing countries, political factors often result in constrained production (e.g., Nigeria,

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[15] Cambridge Energy Research Associates, "Upstream Capital Costs Index," December 5, 2007

Iraq, Venezuela and Iran). The combination of strong demand growth and the need to offset lost production from these countries left the Organization of the Petroleum Exporting Countries (OPEC) at year-end 2007 with only 2.5 million barrels per day of excess capacity, equal to just 3 percent of global oil demand. This contrasts sharply with the greater than 10 million barrels per day of excess capacity that existed in the mid-1980s. This lack of spare capacity leaves the world more vulnerable to oil supply disruptions caused by political events, storm damage to producing facilities, or unforeseen operational problems.

A final reason for recent increases in crude oil prices is the increasing attractiveness of *commodities to financial investors*. Commodity index funds have been developed to provide investors with a financial vehicle to gain commodity price exposure. Investors have moved tremendous amounts of capital into these funds in order to seek higher returns than stock and bond markets provide, or more recently as a "flight to safety", given their concerns about the credit markets, inflation, the U.S. dollar and the direction of stock and bond markets. The funds are disproportionately weighted in energy commodities – one popular fund reports over a 70 percent weighting for energy. It is likely that the large inflow of capital into the commodity funds is temporarily exaggerating upward oil price movements, as well as upwards movements in the prices of other commodities (e.g., copper, nickel, silver, gold, wheat).

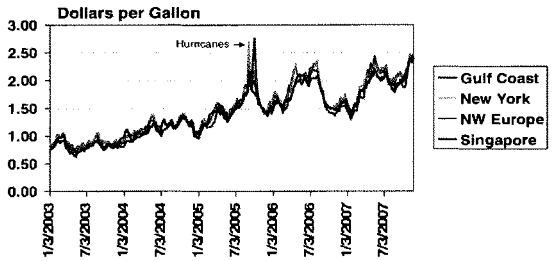
U.S. gasoline and diesel fuel prices

While most of the variation in refined product prices is due to changes in crude oil prices, relatively high global refinery capacity utilization rates in recent years have also contributed. Like crude oil, refined products also trade on global markets. Figure 4 below demonstrates that worldwide wholesale or spot gasoline prices move together. There are occasional temporary regional dislocations due to weather conditions or refinery or transportation outages. However, additional products tend to rapidly move into the supply-short regions and restore the global equilibrium, provided that geographic isolation or specialized product specifications do not interfere with the flow of products.

Figure 4

Globalization in Product Markets

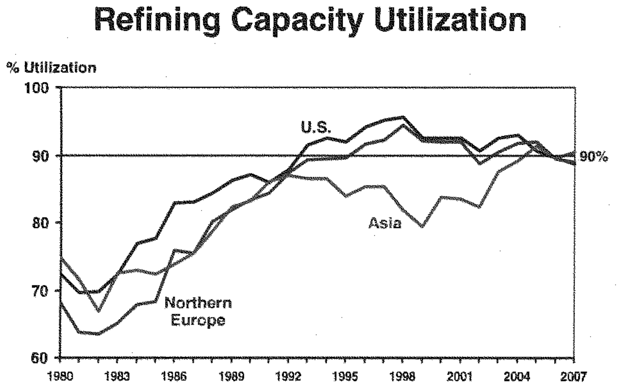
Spot Gasoline Prices in Major Markets



Source: U.S. Department of Energy

Up until the mid 2000s, substantial excess refinery capacity in other nations enabled the United States to benefit from imports of surplus refined products. However, *strong global demand growth* absorbed that surplus, which led to stronger global refining margins over the last few years. Figure 5 below shows that refinery capacity utilization rates in the United States, Europe and Asia have increased substantially in recent decades. High utilization, in turn, led to higher refinery margins that have made economically possible the current round of refinery capacity expansion. The International Energy Agency estimates that 10.6 million barrels per day of global refining capacity is being added between 2007 and 2012. Half of the additions are from incremental expansions in the United States and Asia and half are from new refineries being built in the Middle East and developing Asian nations. In addition to the 1.1 million barrels per day of expansions in distillation capacity planned in the United States by 2012, there are also large-scale upgrading capacity additions that will process increasing amounts of Canadian heavy, sour crude oil, and increase yields of clean-fuels products. [16]

Figure 5



Source: BP Statistical Review, 2007; U.S. Department of Energy for U.S.
2007 = YTD DOE for U.S., COP estimates for other regions

Our industry is often asked why the number of operable refineries in the United States declined from 319 in 1980 to 149 in 2007. According to the Federal Trade Commission, the closures typically involved small, relatively unsophisticated facilities.[17] Between 1973 and 1981, federal government incentives enabled companies to own and profitably operate these small and often inefficient refineries. However, these refineries were hurt by the elimination of these incentives in 1981 and the large capital expenditures that were required to meet government-mandated product specifications (such as clean fuels) and emissions reductions. These expenditures also crowded out investments that might have been made on expansion. However, continuous expansions of the remaining refineries and improved efficiency have enabled the U.S. refining industry to increase crude runs nearly 30 percent since 1983, [18] despite closures of the smaller refineries and the refining industry's historically low returns on investment.

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[16] International Energy Agency, "Medium-Term Oil Market Report," July 2007, pages 54 and 60

[17] U.S. Federal Trade Commission, Bureau of Economics, "The Petroleum Industry: Mergers, Structural Change, and Antitrust Enforcement," August 2004, page 7

Another factor that has caused upward gasoline price volatility is the *proliferation of different grades of gasoline* required by differing federal and state government environmental mandates. The existence of multiple unique product specifications makes it difficult to replenish supplies in the event of a disruption, such as a storm-related refinery equipment outage. Regions with unique product specifications therefore experience greater price volatility than regions with standard specifications. A study by the U.S. Department of Energy indicated that "boutique" specifications did in fact result in upside volatility of gasoline prices,[19] a particular concern since more states are in the process of mandating new "boutique" grades of biofuels.

Additionally contributing to higher gasoline price levels are *higher refining costs*. The refining industry has experienced substantial increases in energy, labor and materials costs. For example, the Nelson-Farrar composite index of refinery operating costs increased by 50 percent since 2002.[20] Contributing to this inflationary pressure is the fact that much of the domestic refining industry is working to expand capacity at the same time, competing for goods and services. Further, the U.S. refining and marketing industries spent $100 billion on environmental projects between 1990 and 2005.[21]

Even as concerns grow over higher gasoline costs, the global *gasoline market is already moving back into equilibrium* due to slowing growth in demand caused by higher prices, startups of refinery capacity expansions and the increased use of ethanol in gasoline. U.S. consumption was relatively strong over the last decade due to growth in vehicle travel and a lack of improvement in average fuel efficiency. Since the early 1990s, consumers purchased a growing percentage of light trucks, including sports utility vehicles, which are generally less fuel-efficient than cars. In addition, manufacturers utilized technological advances to meet consumer demand for increased vehicle size and greater horsepower rather than improve fuel efficiency. However, recent increases in fuel costs have reduced growth in gasoline consumption due to both a slowdown in the growth of vehicle miles traveled and a shift toward purchases of smaller, more efficient vehicles. The Department of Energy estimates that gasoline demand grew by only 0.4 percent in 2007, versus annual growth of 1.5 percent during the last two decades. The combination of increased supplies and lower demand growth has restored some balance in the gasoline market. This is evidenced by the fact that although fuel prices are higher, the increase has not fully reflected the rise in crude oil prices. For example, between July 2, 2007 and March 11, 2008 the price of West Texas Intermediate crude oil increased 53 percent (from $71 to $109 per barrel) but spot gasoline prices increased less than half of that amount (20-25 percent depending on the region), while the average U.S. retail price increased about 10 percent (from $3.00 to $3.27 per gallon).[22]

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[18] U.S. Department of Energy, Energy Information Administration, U.S. Weekly Crude Inputs Into Refineries, website (11.8 mmbd in 2003 and 15.2 in 2007)

[19] U.S. Department of Energy, Energy Information Administration, "Gasoline Type Proliferation and Price Volatility," September 2002, page 4

[20] Oil and Gas Journal data base, "Nelson-Farrar refinery operating index," monthly as of November 2007

[21] American Petroleum Institute, "Environmental Expenditures by the U.S. Oil and Gas Industry," June 2007, page 4

The other shift occurring in global and U.S. product markets is the *strengthening of diesel fuel prices relative to gasoline prices.* This is caused by tightening global diesel markets as Europe shifts its passenger fleet to consume diesel fuel and as diesel fuel demand grows in other parts of the world. Refineries have not yet had time to shift their production capabilities, and only limited changes are possible with existing equipment. However, new diesel fuel production capacity is being added at a number of refineries. Also contributing to recent price increases are government-mandated shifts in production to ultra-low-sulfur diesel fuel in the United States and Europe. This fuel is more expensive to manufacture, and the lack of global capacity to produce diesel fuel with the required specifications limits the ability to import fuel. As a result of these global forces, U.S. prices for on-road retail diesel fuel averaged nine cents per gallon above gasoline prices since 2005, compared to averaging 5.5 cents per gallon below gasoline prices between 1995 and 2004.[23]

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[22] U.S. Department of Energy, Energy Information Administration, Weekly Petroleum Status Report, spot WTI at Cushing, spot conventional regular gasoline at NY Harbor, Gulf Coast and Los Angeles, U.S. retail motor gasoline, all grades all formulations

Industry Profits: Addressing Common Misperceptions

Oil and natural gas industry earnings are highly cyclical, as they are with other commodity industries. Profits have increased in recent years with the strength in underlying commodity prices, but costs have escalated rapidly and are still rising. In fact, Morgan Stanley estimates that the returns on capital employed for exploration and production of the integrated oil companies peaked in 2005.[24] Morgan Stanley also estimates that from 2008 to 2012, new upstream investments will require crude oil prices of nearly $85 per barrel (West Texas Intermediate) to be profitable at the industry's cost of capital. Given continuing cost increases, Morgan Stanley believes that crude oil prices by 2012 of approximately $90-100 per barrel will be needed to justify investment.[25] Thus, higher prices today reflect higher replacement costs.

There is a common misperception that the absolute dollar amount of major oil company earnings is indicative of the industry's profitability. Rather, its earnings reflect the industry's enormous scale and the capital investment needed to replenish depleting supplies. Constrained resource access at home and abroad has required international oil companies to undertake increasingly large, complex and risky projects that host governments may not have the financial strength, skills or technology to undertake on their own. A typical large ConocoPhillips exploration and development project requires several billion dollars of initial investment and may not generate revenues for over a decade from project sanction. A single large offshore platform in the Gulf of Mexico designed to operate in thousands of feet of water costs more than $1 billion to develop. A project to produce and deliver liquefied natural gas currently may cost between $7-21 billion, depending on its size, location and complexity of the project. The proposed Alaska natural gas pipeline is expected to cost $25-40 billion. Only large companies with substantial financial capacity and technical resources can effectively develop these projects, while sufficiently diversifying the number of projects and geographies to manage the risk.

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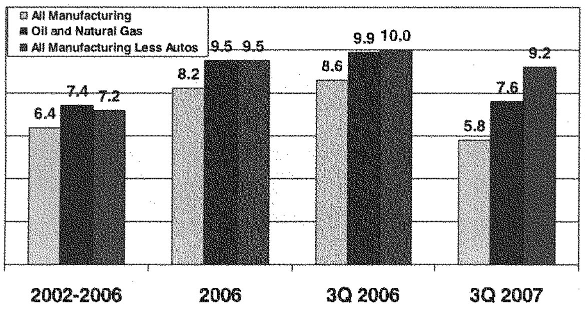
[23] U.S. Department of Energy, Energy Information Administration, Weekly Petroleum Status Report, U.S. Gasoline and Diesel Retail Prices
[24] Morgan Stanley Research, "Integrated Oil," March 14, 2008, Exhibit 18, page 12
[25] Morgan Stanley Research, "Integrated Oil," March 14, 2008, page 12

There is also a common misperception that energy industry earnings and returns on investment are higher than those in other industries. Figure 6 below shows that the industry's earnings are comparable to those of other manufacturing industries.

Figure 6

Industry Earnings

(Cents per dollar of sales)



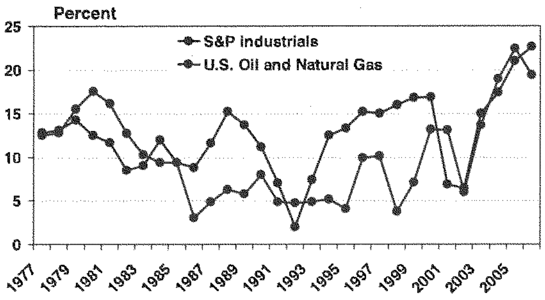
Source: U.S. Census Bureau for U.S. manufacturing and Oil Daily of the oil and gas industry

Figure 7 below, based on U.S. Department of Energy data, shows that the return on investment for the oil and natural gas industry is currently comparable to average returns for the S&P industrials, after lagging those returns for many years.

Figure 7

Industry Return on Investment

Net Income / Net Investment in Place



Source: U.S. Department of Energy, Energy Information Administration, Performance Profiles of Major Energy Producers, various issues and 2005 S&P figure compiled by PWC from Compustat data

Another common misperception is that the oil and natural gas industry is not reinvesting its earnings to develop new supplies. Figure 8 below shows that investments have increased along with earnings. For example, 2006 investments of more than $174 billion increased by 29 percent over 2005. Between 1992 and 2006, the U.S. oil industry invested more than $1.25 trillion in a range of long-term energy initiatives, compared to net income of $900 billion. Some also express concerns over the industry's rate of stock repurchases. However, according to U.S. Department of Energy data, for the last 11 years, the industry spent only 21 percent of net income on stock repurchases, compared to the S&P industrials repurchase rate of 52 percent.[26] Despite the relatively low stock repurchase rate, the oil and gas industry would likely reinvest at even higher rates if governments made more resources accessible.

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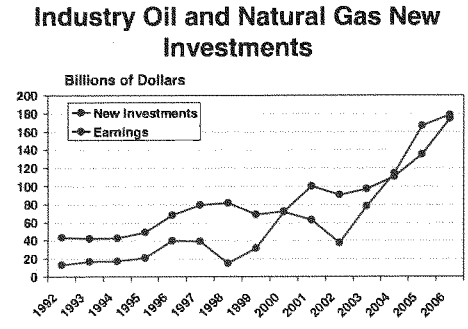
[26] U.S. Department of Energy, Energy Information Administration, "Performance Profiles of Major Energy Producers 2006," December 2007

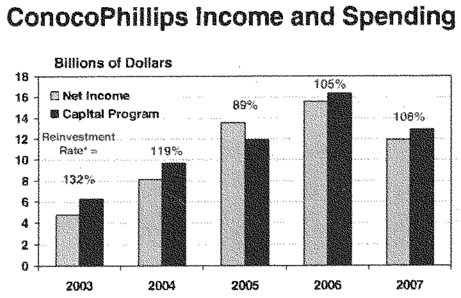
Figure 8



Source: Ernst & Young

ConocoPhillips' reinvestment rates have typically exceeded its earnings. Figure 9 below shows that between 2003 and 2007 the company's average reinvestment rate as a percent of net income averaged 106 percent. In addition, capital spending increased nearly 150 percent between 2003 and our projected 2008 spending level of about $15 billion. A final point is that while our earnings are numerically large, they in fact reflect the substantial capital investment required to replace reserves and achieve growth. For example, ConocoPhillips earned nearly $12 billion in 2007, but spent close to $13 billion.

Figure 9



* Reinvestment rate as a percent of net income
Source: ConocoPhillips' SEC filings

Path To A Sound Energy Policy

ConocoPhillips believes there are several concrete steps that Congress can take to enhance the nation's future energy security. We want to first emphasize that despite the current tight market, the world is not short of energy supplies. Rather, it lacks sufficient political will to develop the vast fossil fuel and alternative resources that are available. Additionally, it is vital to point out that there is no "silver bullet" that would quickly and inexpensively replace fossil fuels and create energy security. Instead, the United States must bring all economic sources of energy to the marketplace. Doing so will require strong political leadership and determination, as well as, sound insight into the realities of the energy market. We need no less than a national commitment to achieve security of both near- and long-term energy supply and policies that outline a clear path to follow. ConocoPhillips believes that a sound U.S. energy policy must incorporate the six actions explained below.

Encouraging conventional supplies

Although the United States has only 3 percent of the world's remaining oil and natural gas proved reserves, this is due in part to governmental policy. We could increase U.S. reserves by drilling in the vast onshore and offshore areas that are currently off limits. Altogether, these areas are estimated to hold 80 billion barrels of recoverable oil and natural gas equivalent – enough to double current U.S. reserves.

Industry critics frequently charge that since one area or another only offers a few months or years of supply, it should not be developed. ConocoPhillips believes that it is economic folly to instead transfer $8 trillion dollars – the possible market value of these potential resources at current oil prices – to other countries through imports instead of keeping that money at home and gainfully employing thousands of Americans. Unless Congress acts to improve access to domestic resources, the United States must accept oil import dependence at the current rate of about 60 percent, or even higher in the future. Therefore, the federal drilling moratoria on non-sensitive lands should be suspended and drilling allowed under strict environmental oversight. Industry technology and operating practices have made quantum leaps in the years since these moratoria were enacted. Our national vulnerability no longer allows the luxury of ignoring so much energy potential. It is often said by those opposed to providing more access that, "We cannot drill ourselves out of our domestic energy situation." That is true, as is the fact that, "We cannot expect an aggressive program to develop alternative and renewable fuels to provide needed energy security overnight no matter how aggressively we develop them." A balance of both is required.

To satisfy projected demand, the United States and the world also need OPEC nations, and particularly those with large reserve holdings, to expand their production capacity. We are concerned about the mixed signals that U.S. policymakers are giving these countries. On one hand the United States urges them to increase production, while on the other it threatens to back out a substantial portion of Middle East oil imports, or to sue OPEC. These countries may not expand their production capacity to the extent that is needed if they do not believe there is a sustained market for their crude oil.

Congress should also facilitate the building of the critical infrastructure needed to deliver energy supplies to the public. The United States needs more ethanol unloading and blending terminals, more pipelines and power transmission lines, and more refinery expansions. But duplicate and overlapping federal and state laws, and overly long and difficult regulatory processes, discourage or delay such infrastructure additions, particularly for refineries. For example, ConocoPhillips applied in May 2006 for a permit to expand our Wood River refinery in Illinois, and we still do not have a final permit. At our refinery in Wilmington, California, local permit challenges and litigation have threatened an ultra-low-sulfur diesel fuel project since 2004. An expansion at our Rodeo refinery near San Francisco took 28 months to permit and only after a compromise was reached with the state Attorney General. These expansions are designed to increase supplies of transportation fuels – precisely as Congress would wish. In cases like these, where infrastructure is clearly needed to serve the national interest, Congress should expedite federal and state permitting processes to ensure a balance between federal, state and local and special interests.

A related issue is the proliferation of different types of gasoline. State mandates require production of 16 localized "boutique" blends for particular markets, multiplied by three different octane grades and by different winter and summer blends. Also, some states now require boutique biofuels blends. The result is a profusion of different fuels, each with its own specifications. These boutique blends prevent the transfer of fuels from one region to another in the event of logistical or operational challenges. This causes shortages and price spikes. Congress could alleviate these problems by setting uniform national fuel requirements.

Optimizing biofuels production

Moving to biofuels, the Energy Independence and Security Act of 2007 mandates the use of 36 billion gallons by 2022. While this is a laudable objective, some improvements to that statute are needed.

First, the creation of different "silos" or categories of biofuels reduces flexibility in complying with the mandate, which is likely to cause inefficiency and increase costs. The Act also presumes to know what the best technologies will be 14 years from now. Congress should not attempt to pick "winning" technologies. Instead, a more sound approach would be to enact incentives or mandates that are both technology-neutral and fuel-neutral. For example, it is not reasonable for biodiesel to qualify for tax support, while renewable diesel fuel does not. As long as both processes use renewable feedstock, support should be neutral and treatment equal.

A second concern is mandating a level of biofuels use exceeding 15 billion gallons. Such concentrations will exceed the capability of both the vehicle fleet and the supply delivery infrastructure (ethanol's corrosiveness requires use of special equipment). Also, advanced biofuels that do not use potential food sources as a feedstock cannot be produced commercially today. The Environmental Protection Agency has the ability to waive high mandated volumes if technology and production have not advanced sufficiently. However, such waivers are made known only a few months before the start of a compliance year, which does not allow fuel providers sufficient time to plan optimized and efficient compliance activities.

A third concern is the current 54-cent-per-gallon tariff on imported ethanol, which penalizes lower-cost and less carbon-intensive imports, such as from Brazil. This tariff should be phased out or eliminated.

Finally, ConocoPhillips is quite concerned about the potential for governments to layer on overlapping policies. For example, we hear that policies are being considered to add a national low-carbon fuel standard on top of a low-carbon renewable fuel standard. The overlap between these programs would further confound the overlap of state programs previously discussed. If the United States continues to overly constrain its production and supply systems, optimal solutions will cease to exist, and the result will likely be higher fuel costs and possibly even supply outages.

Encouraging alternative and unconventional sources

While alternative and unconventional energy sources will be essential in the future, it is important to recognize that new technologies take time to commercialize and usually cost more than conventional supplies. Here, Congress is at risk of too strongly favoring politically expedient energy sources. The market should decide which are the best technologies in order to avoid over-reliance on old technologies or uneconomical energy sources.

We would encourage Congress to also recognize that, although oil sands and unconventional fossil fuels such as oil shale and coal gasification are more energy- and carbon-intensive than conventional sources today, they could substantially improve energy security because these resources are abundant in the United States and Canada.

There is significant opposition to developing these sources unless carbon capture and storage is also employed. However, until the U.S. establishes a working regulatory framework for greenhouse gas emissions, it would not be economic to store carbon from these sources. It would also be risky to make these investments given the uncertainty over when and whether the United States will enact legislation to regulate carbon and the parameters of such a program.

ConocoPhillips suggests that in order to improve both energy and climate security, Congress should put a program in place to encourage commercialization of large-scale carbon storage projects from these types of oil resources – without waiting for enactment of a full cap and trade program. To facilitate this process, the federal government can commit to provide "carbon-price insurance" for carbon storage projects for up to one million barrels per day of oil supply and three billion cubic feet per day of natural gas supply by 2020. This would represent about 5 percent of U.S. oil and natural gas demand. The government could auction this insurance to the projects that yield the largest reductions in carbon intensity relative to cost.

For example, if a winning bid was a project with a storage cost of $40 per tonne of carbon dioxide avoided, the government would guarantee that the project would have the $40 per tonne to store carbon. If, in the interim, a federal cap and trade program was implemented that brought the cost of carbon allowances to $40 per tonne, the project would fully assume the storage cost and there would be no government outlay.

Lowering the carbon intensity of energy supplies

We would encourage future Congressional policies to focus on lowering the carbon intensity of U.S. energy supplies, and work to encourage the global community to join in this effort.

Congress could take action to reduce our carbon footprint by establishing a baseline, and a system of incentives and penalties to ensure that we meet this baseline. The first step would be to create a mandatory framework that would lower our greenhouse gas emissions, and set a price for carbon avoidance. This could be done by either a tax or a cap and trade system. This step would influence investment decisions across the entire economy.

Incentives should be offered for development of carbon capture and storage. Companies are ready to begin making the required investments, but first government must establish a value for carbon avoidance and national legal and regulatory frameworks for liability and permitting issues. And the government should provide access to federal lands that offer the potential for underground carbon storage.

Next, Congress should encourage greater use of renewable sources – such as solar and wind power – by extending their investment tax credits by five years at a time. This would help provide the financial certainty needed for investment. Development of these renewable power sources benefits the public at large and should be paid for with public funding, not by imposing discriminatory tax provisions on three or four American companies, as is being considered. The United States must develop more of every form of energy, including oil and natural gas. Developing low-carbon energy supplies should be a national priority, and one industry should not be required to fund this effort alone.

Congress should also encourage greater use of nuclear power, which represents higher percentages of total electricity supply elsewhere than in the United States. To do so, the federal government should fulfill its commitment to dispose of waste generated by nuclear power plants. It should also sponsor research into advanced technology that uses the fuel more completely – while reducing waste volumes and half-life – and lowering proliferation risks.

Improving energy efficiency

The Energy Independence and Security Act of 2007 did much to improve fuel efficiency standards for light-duty vehicles and appliances, and ConocoPhillips commends Congress for this bold action. We also encourage governments to take action to slow the rate of growth in peak electricity use – an important step, given the strong historical growth in electricity consumption and rising reliance on natural gas to generate power during peak demand periods. Electricity represents 40 percent of current U.S. energy consumption, compared to 25 percent in 1970.

Over the last decade a substantial amount of natural-gas fired power generation capacity was added in the United States due to the attractive economics of combined cycle gas turbines and the clean-burning characteristics of gas. As a result, electricity costs in many regions are highly dependent on natural gas prices during peak daytime demand periods. Therefore, to improve availability of natural gas as well as electricity, we need to advance the construction of natural gas pipelines from Alaska and the Mackenzie Delta in Canada, and of new liquefied natural gas terminals. All have been delayed due to hyper-inflation in costs, local politics and special interests.

Government could also help reduce peak electricity demand by enacting regulatory and fiscal incentives that encourage utilities to reduce electricity demand by offering more transparent real-time pricing that shows consumers the cost of power as they use it. A key technology to enable this pricing, called "smart meters," already exists.

Encouraging technology innovation

It is also vital that Congress encourage investment in new technologies in all areas of energy development. A variety of technological advances are needed to help maximize recovery of conventional resources, enhance ability to operate complex projects in harsher environments, improve environmental performance, develop new alternative and unconventional energy sources, reduce the carbon intensity of energy supplies, and improve the efficiency of energy use across the entire economy.

Both the public and private sectors should increase spending on energy research and development. Government technology investments should be made in a transparent and market-based manner, with incentives going to the best ideas.

Government could further drive technological innovation through greater support of education. With half of the energy industry's technical work force expected to reach retirement eligibility in the next 10 years, there is growing need for more university students majoring in engineering, geology, geophysics and the other technical disciplines. The United States also needs better secondary education to prepare its students for rigorous college study.

Recognizing the increased need for training for the many new employees entering our industry, and to help our existing employees reach their full potential, ConocoPhillips recently purchased land in Louisville, Colorado, to develop a center for corporate learning. We are also building a global technology center at this location to foster innovative research and the development of new technology.

Conclusion

Improving energy security and reducing the risk of climate change are formidable challenges. As one of America's leading energy suppliers, ConocoPhillips intends to be part of the solution. We believe Congress can provide critical leadership in:

- Increasing domestic resource access,
- Improving the ability to permit key energy infrastructure in this country,
- Enacting a mandatory regulatory framework for reducing carbon dioxide emissions so we can invest to reduce the carbon intensity of the nation's energy supplies.

We understand that many of these recommendations may involve differences of opinion between government and industry, but we encourage an atmosphere of cooperation and are eager to engage with you in finding solutions for meeting this country's energy needs.

The United States has much to gain from a healthy U.S. energy industry that can compete domestically and globally to expand the energy supply available to the United States. Actions taken to weaken the U.S. energy industry will accelerate the shift in control of resources into the hands of national and foreign oil companies at our expense. China, India, the European Union and other nations are deeply engaged in helping their energy industries capture resources to meet the future energy needs of their constituents. We must work together to ensure that our nation's energy needs are met.

Again, Mr. Chairman, thank you for inviting ConocoPhillips to participate in today's hearing. We look forward to working with this important committee in the days ahead.

The CHAIRMAN. Thank you, Mr. Lowe.

And our final witness is Mr. Robert Malone, who is the Chairman and President of BP America. Mr. Malone has led BP America since 2006.

We welcome you, sir. Whenever you are ready, please begin.

STATEMENT OF ROBERT A. MALONE

Mr. MALONE. Thank you, Mr. Chairman, Ranking Member Sensenbrenner, members of the Select Committee.

Good afternoon. My name is Bob Malone, and I am the Chairman and President of BP in America.

We are the nation's largest producer of domestic oil and gas and one of the nation's largest energy investors. We expect to spend here in the United States $30 billion over the next five years to expand and extend production of natural gas from the Rocky Mountains west to renew critical oil and gas infrastructure on the North Slope of Alaska, to continue development in the deep water Gulf of Mexico, and to increase gasoline production from key midwest refineries.

In the area of alternative energy, we are nearly doubling the capacity of our Frederick, Maryland solar plant, the largest integrated solar manufacturing facility in the United States.

By the end of this year we expect to have 1,000 megawatts of U.S. wind power capacity on line, increasing to 2,400 megawatts by the end of 2010. That is enough to power more than 700,000 homes.

We are already one of the largest blenders of ethanol in the nation. However, over the next decade, we will invest more than 500 million in the search for a new generation of biofuel that contains more energy, has less impact on the environment, and which is not made from a food crop.

We know high energy prices are having an adverse impact on our nation's economy and your constituents and our customers. We cannot change the way the world market relies and this nation relies on 60 percent of its oil from foreign countries. But we can work with this Congress, with the administration, and with governments and consumers across this nation to move towards greater energy security and a lower carbon energy future.

To be clear, BP America is working hard to expand and to diversify U.S. energy supply and is committed to reducing the environmental impact of both energy production and consumption. Our operations span the country, and many employ technologies that did not even exist a decade ago.

Our investment across the entire energy spectrum is huge. Over the last five years, we have invested $31.5 billion in development of U.S. energy security. During 2007, we invested three-quarters of a billion dollars or ten percent of our capital budget on alternative energy.

But the hard truth is that even the major improvements in energy efficiency with the rapid growth of solar wind and biofuels, the United States will consume more oil, more natural gas and coal in 2030 than it does today. The United States with five percent of the world's population consumes 25 percent of the world's daily oil production.

The U.S. should produce more of the energy it consumes, and it has a responsibility to use that energy wisely. U.S. energy policy must address both energy supply and energy demand. On the supply side, we support incentives for alternative energy, but taxing one form of energy to encourage production of another will reduce our ability to keep up with the growing U.S. energy demand. The result will be less investment, less production, tighter energy markets, and potentially even higher prices at the pump.

This nation should be encouraging production of all forms of energy, especially oil an gas. On the demand side we have to encourage conservation and drive energy efficiency.

Mr. Chairman, members of the Committee, in the notice of this hearing you expressed a desire for a real conversation about energy. I am here on behalf of BP to have that conversation. The energy challenge facing this nation is enormous. BP is serious about bringing new sources of oil and gas to the U.S. market. We are also serious about building a sustainable, profitable alternative energy business that is capable of delivering the clean, affordable power that consumers want.

My company stands ready to work with you and others to address the energy and environmental needs of this nation.

Thank you.

[The statement of Mr. Malone follows:]

House Select Committee on Energy Independence and Global Warming

April 1, 2008

Written Testimony

Robert A. Malone
Chairman & President, BP America

My name is Bob Malone and I am Chairman and President of BP America.

BP appreciates the opportunity to provide the Committee with information concerning our operations and investments. I am proud of our investments and the commitment they represent to the development of a secure energy future in the US. I am here today to convey BP's perspective about the marketplace and share our understanding of the choices we as Americans must make in order to ensure a diverse and adequate energy supply for future generations.

We are privileged to be the nation's largest producer of domestic oil and gas and one of the nation's largest energy investors. In 2007 BP's US production of oil was 513,000 bpd and gas production was over 2 Bcfd.

We operate the largest integrated solar manufacturing plant in the United States in nearby Frederick, Maryland.

We are major investors in wind generation and have amassed a land portfolio capable of potentially supporting 15,000 megawatts (MW) of wind generation, one of the largest positions in the country. We are building 700 MW of wind generation this year and expect to have an installed capacity of 2,400 MW of wind power by the end of 2010.

We are one of the largest blenders and marketers of biofuels in the nation. Last year, BP blended 763 million gallons of ethanol with gasoline and we are underwriting cutting edge research – investing more than $500 million over the next 10 years –in the search for a new generation of biofuels that contain more energy… have less impact on the environment… and which do not reduce the supply or increase the cost of food.

We are attempting to develop hydrogen power generation with carbon capture and sequestration. In California we are evaluating a $2 billion, industrial scale project that will use petroleum coke to make hydrogen for use in power generation. Carbon dioxide, a byproduct of producing hydrogen, will be captured and safely and permanently stored underground.

In short, BP America is working to expand the supply of energy available to the United States and is committed to continue reducing the environmental impact of both energy production and consumption.

Our approach has been shaped by a hard truth.

Hard Truths

The US today is faced with tremendous energy challenges. It is experiencing the impact of years of policies, poor market dynamics and company decisions that have limited access to resources, discouraged development and constrained new investment to meet growing consumer demand for energy. BP recognizes the negative effects high prices have on the economy and the consumer. We alone can't change the conditions that brought us here. Energy companies, policymakers and consumers all have a role to play in creating a new energy future for the US.

This relationship must be shaped by the recognition that the US economy needs both to better conserve energy and to produce more energy of every type to meet growing demand. We need to invest in conventional oil and gas. We also need to invest in renewables and alternatives to begin the transition to a low carbon future. However, we must all understand that this future is many years away and that renewables and alternatives will not make a material contribution to total US energy supply for many years.

This view is reflected in a recent study issued by The National Petroleum Council in July of 2007 - Facing the Hard Truths About Energy. It was an in-depth, comprehensive review of the entire energy sector that benefited from participation and support from a diverse group of stakeholders and more than 1000 persons/groups involved in energy.

I have integrated its observations and conclusions below and added emphasis as necessary.

> *There is no single, easy solution to the global challenges ahead. Given the massive scale of the global energy system and the long lead-times necessary to make material changes, actions must be initiated now and sustained over the long term. Over the next 25 years, the US and the world face hard truths about the global energy future:*
>
> - ***Coal, oil, and natural gas will remain indispensable to meeting total projected energy demand growth****.*
> - *The world is not running out of energy resources, but there are accumulating risks to continuing expansion of oil and natural gas production from the conventional sources relied upon historically. These risks create significant challenges to meeting projected total energy demand.*
> - *To mitigate these risks,* ***expansion of all economic energy sources will be required, including coal, nuclear, biomass, other renewables, and unconventional oil and natural gas****. Each of these sources faces significant challenges including safety, environmental, political, or economic hurdles, and imposes infrastructure requirements for development and delivery.*
>
> *The Council proposed five core strategies to assist markets in meeting the energy challenges to 2030 and beyond. All five strategies are essential, the US must:*
>
> - ***Moderate the growing demand for energy*** *by increasing efficiency of transportation, residential, commercial, and industrial uses.*
> - ***Expand and diversify production*** *from clean coal, nuclear, biomass, other renewables, and unconventional oil and gas; moderate the decline of conventional domestic oil and gas production; and increase access for development of new resources.*

- ***Integrate energy policy into trade, economic, environmental, security, and foreign policies****; strengthen global energy trade and investment; and broaden dialogue with both producing and consuming nations to improve global energy security.*
- ***Enhance science and engineering capabilities*** *and create long-term opportunities for research and development in all phases of the energy supply and demand system.*
- ***Develop the legal and regulatory framework*** *to enable carbon capture and sequestration. In addition, as policymakers consider options to reduce carbon dioxide emissions, provide an effective global framework for carbon management, including establishment of a transparent, predictable, economy-wide cost for carbon dioxide emissions.*

The above excerpts only begin to touch upon the level of analysis contained in the nearly 400 page report. This report provides a complete assessment and a non-partisan roadmap on how and what to do in the area of energy policy.

BP Operations in America

BP's US operations have been challenged over the last few years - significantly impacted by a series of accidents and operational problems in both our refining and upstream businesses. BP has made significant investments to upgrade its assets, strengthen operations, improve its safety performance, and enhance compliance to prevent another such period from happening again.

Over the last 5 years, BP in America earned approximately $31.7 billion after-tax. Income taxes paid over the period have steadily increased to an effective rate of 37% in 2007 – with BP paying over $14 billion in income tax over the period.

There are some who say oil industry profitability is excessive. But this ignores the size and scale of our business. Comparing oil industry performance to that of the broader market average (Exhibit 1) shows that our earnings are comparable. Looking at all the industrial sectors, oil and gas industry performance was in the middle of the pack (Exhibit 2).

Regarding investments, over the last 5 years BP has reinvested in the US $31.5 billion into projects across the energy spectrum. And, over the next decade, we expect to continue to invest an average of $6 billion a year.

These investments stretch across the entire country, from the Gulf of Mexico to the North Slope of Alaska and from the East Coast to the Midwest and the West Coast. The company's major spending programs also touch every major segment of the energy industry, from exploration and production of oil and natural gas through refining and distribution of fuel products, as well as alternative energy and biofuels. By heavily investing in a diverse range of energy sources – from traditional oil and natural gas production to alternative and renewable energy including solar, wind and hydrogen power – BP is helping meet America's energy needs today while ensuring a more secure energy future.

Below is a partial list of our current major investments:

Energy Biosciences Institute - $500 million
The institute focuses on exploring bioscience applications and applying them to the production of new and cleaner energy, principally renewable fuels for road transport. The institute is a joint collaboration with the University of California Berkeley, University of Illinois – Urbana Champaign and the Lawrence Berkeley National Lab. The project will look at the entire biofuels value chain – from feedstock to enzymes to process and on through to advanced biofuels molecules.

Colorado Natural Gas - $2.4 billion
Increase ultimate recovery of coalbed natural gas from the San Juan Basin of southwestern Colorado by an estimated 1.9 trillion cubic feet. The 13-year development program would increase current BP net production of 425 million cubic feet per day by more than 20 percent, and maintain production above present levels for more than a decade.

Whiting refinery modernization - $3.8 billion

Upgrade and expand the Whiting refinery to increase Canadian heavy crude oil processing capability by about 260,000 barrels per day. The project also has the potential to increase motor fuels production by about 15 percent, or about 1.7 million additional gallons of gasoline and diesel per day.

Wind Power - $700 million
BP and its partners invested about $700 million in 2007 to develop wind capacity throughout the US, including California, Colorado and Texas. During 2008, BP will construct 5 US wind farms with a total generating capacity of 700 MW and a total value of over $1.5 Billion. This will bring our total installed capacity of wind generation to over 1,000 MW by the end of 2008. By 2010, we expect to have 2,400 MW installed. This is enough power to meet the needs of 720,000 households.

Solar Manufacturing Expansion - $97 million
BP is expanding the BP Solar manufacturing facility in Maryland, nearly doubling its capacity. When completed in 2009 the plant will have a manufacturing capacity of 150 MW in its casting and sizing processes.

Deepwater Gulf of Mexico - $20 billion
BP is increasing exploration and production of oil and gas from deepwater reservoirs in the U.S. Gulf of Mexico. BP will continue development plans to explore new lease area and bring producing areas on-line (Thunderhorse, Atlantis...).

Alaska renewal - $685 million
BP is investing hundreds of millions of dollars in Alaska each year to commercialize and produce the billions of barrels of known oil resources in our Alaska portfolio. We have enough known oil and gas resources to sustain production for the next 50 years but this will require billions of dollars in new investments.

Wyoming Natural Gas - $2.2 billion

Over the next 15 years BP will double our natural gas production in Wyoming. Several hundred new wells are planned in the Wamsutter Field, BP's largest onshore development drilling program.

Husky Energy Joint Venture – $5.5 billion
BP and Husky will jointly develop Canadian oil sands resource and upgrade and modernize BP's Toledo, OH refinery. When fully operational the project is expected to deliver an incremental 200,000 bpd of oil to the US market and allow Toledo to produce 600,000 gpd more product to Midwest consumers.

However, as we look to the future, the US investment climate is deteriorating. Various efforts have unnecessarily impeded viable and critical infrastructure projects; promising development areas have been declared off-limits; existing manufacturing operations have been challenged in their efforts to upgrade and expand; and new taxes have been proposed which will discourage future energy resource development. Furthermore, these stumbling blocks exist across the energy profile and are not just confined to oil and gas activities.

Support for Renewables

Emblematic of these gaps are policy discussions concerning how to support and fund the development of alternative energy resources like wind, solar and biofuels. Not surprisingly, policymakers and consumers generally support efforts that promote the development of renewable energy. As is reflected in its investment portfolio, BP concurs with this sentiment. However, there is significant divergence of opinion regarding the question of how to fund the necessary financial incentives.

BP strongly supports the renewal of incentives for wind, solar, and biofuels. They are an important part of why the US has been so successful in developing its renewable energy sector, but we cannot support a tax package that discourages efforts to bring on other much needed energy sources (oil and gas production). As shown in

Exhibit 3, the oil industry is already heavily taxed compared to others in the manufacturing sector. In fact, the effective rate for 2006 was nearly double that for all manufacturing companies.

Despite the growth and development activity we are experiencing in alternatives, they cannot close the supply gap that is projected to occur over the next 20 year period. Fossil fuels like coal, oil, and natural gas will be critical to meeting expected energy demand growth.

Our nation, with 5 percent of the world's population, demands 25 percent of daily world production. I don't think this is sustainable. The US must produce more of the energy it consumes and has a responsibility to use that energy wisely.

Based on our experience in developing renewable infrastructure, there are many non-financial opportunities that would be effective in stimulating additional investment. These include:

- Expedited siting and permitting of transmission to allow for the distribution of clean power (wind, solar) from generating areas to load centers ;
- Providing for market, time-of-day pricing for solar power installations to allow homeowners and others to provide excess power back to the grid during the peak demand periods at the same rate utilities charge others;
- Adopting a renewable portfolio standard (RPS) that requires power generators to utilize renewable sources like wind and solar in their mix. Experience has shown that in those states that have a RPS, renewable usage has increased significantly.

Biofuels

Similar policy gaps exist in the area of biofuels. Last year's energy bill created significant opportunities to develop and grow the contribution of biofuels to the transportation fuels market. BP shares the view of policymakers that biofuels may be able to attain penetration rates of 30% by 2030 thus playing a huge role in meeting future transportation needs. However, the legislation created new challenges that could in the end create market distortions, supply disruptions and higher consumer prices if not adequately addressed. First, the implementation timetable is very aggressive, creating a risk to delivery of fuel in sufficient quantities to the markets where it is needed. Congress, while mandating biofuels blending, did nothing to ensure that the market was prepared to accommodate the huge storage, transportation and delivery infrastructure requirements necessary to get the product to the consumer.

Perhaps the greatest concern is that if biofuels producers can't supply – fuel retailers pay a penalty; if biofuels manufacturers can't produce – fuel retailers still pay a penalty. In order to make the emerging biofuels market work effectively, there must be a shared obligation with biofuels producers to ensure product reaches the consumer at the lowest possible price. We look to work with stakeholders to ensure this is done effectively as the implementing regulations are drafted.

Climate policy

Our nation will face difficult choices as we take steps to foster economic growth, ensure our nation's energy security and protect the environment. Chief among these environmental concerns is that of global climate change.

A decade ago BP was the first oil company to acknowledge the need to reduce greenhouse gas emissions. In the years since, we have worked to reduce emissions from our own operations and to provide consumers with cleaner, lower carbon energy options. However, because the energy industry is so large, diverse and complex, there are limits to what a single company or a single facility can do to address this global problem.

For that reason, BP has long advocated for the creation of a single, mandatory US greenhouse gas emissions registry and a market-based price for carbon. Market-based programs deliver the greatest and fastest reductions at the least cost. Just as important, they create a level playing field, meaning that everyone must be part of the solution and first movers aren't placed at competitive disadvantage.

The fact that Congress has not yet addressed national climate policy has not deterred some from trying to impose requirements as if a national policy existed.

Most recently, legislation has been adopted to discourage development of Canadian oil sands - the single largest oil resource base outside of Saudi Arabia. Additionally, a bill has been introduced to prevent the US from utilizing its world leading resource position in coal for power generation. Similarly, efforts are underway to either allow or encourage state or local jurisdictions to try and impose CO2 reduction targets on individual projects in order to make them uncompetitive and further discourage resource development.

Why do I mention these examples? They clearly represent efforts to limit energy development opportunities that would enhance US energy security, economic development and environmental protection. One may only conclude that by limiting engagement, understanding and dialogue concerning the choices facing consumers, the public will accept the notion that all fossil fuel energy development should be discouraged.

We believe Congress should set policy goals and allow the market to decide which technologies best deliver upon the objectives it sets. To do otherwise stifles the very technology breakthroughs and developments Congress supports.

Energy imports

Over the years, US policy has, in effect, encouraged oil and gas providers to look beyond the US border to meet growing US energy demands, yet policymakers often question our reliance on foreign oil imports. Policymakers also implore OPEC to produce and develop its own oil resources in order to reduce crude oil prices in the US. I question whether it is reasonable to rely on OPEC to solve a problem abetted by inconsistent US policy?

The US should strive to more fully develop its own resource base – to make a greater contribution to world oil supply – otherwise we will increasingly rely on imported energy to meet the needs of our growing economy.

Industry frustration levels are high because we see the potential to greatly expand US development opportunities (Exhibit 4). In fact, we have experience in the US Gulf of Mexico that proves with the proper policy enablers industry will respond overwhelmingly. Since 1985, oil production from the deepwater Gulf has increased 15-fold, from 58,000 to 870,000 barrels per day. Despite water depths in excess of 1 1/2 miles, well depths as great as 30,000 ft and operating temperatures and pressures greater than we have ever experienced, industry responded to Government encouragement to invest, explore and develop this resource base. This is a huge success story as the deepwater Gulf now accounts for every sixth barrel of oil produced in the US.

We have no reason to believe that this success can't be replicated in other areas across the US.

Energy Markets

Your hearing notice indicated an interest in understanding the drivers behind the run-up in crude oil and gasoline prices. The following provides a brief synopsis of our market view.

Crude oil prices have increased sharply in recent years and have recently set record inflation-adjusted highs. The US benchmark West Texas Intermediate rose from an average of about $26 per barrel in 2001/02 to $72.20 in 2006. So far this year, WTI has averaged $97.27 (through March 24th), and peaked at $110.35 on March 13th.[1]

Tightening oil market fundamentals have been the key driver of higher prices. Economic growth is always a key driver of oil demand, and the world has just seen the strongest 5-year period of global economic growth since the early 1970s. While China has seen strong (and particularly energy-intensive) economic growth, so has the rest of the world.

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[1] Source for price data: Platts

Complicating this growth profile, some developing countries and oil exporters with rapidly growing economies subsidize prices in their domestic markets, thereby shielding consumers from the impact of rising world prices. For example, Venezuelan drivers pay about 7 cents per gallon—the world's lowest price—and Iranian drivers pay about 42 cents per gallon.[2]

Supply factors have also contributed to higher prices. Production is declining in mature provinces such as the US, the North Sea, and Mexico. Growth in Russian production has slowed. Shortages of labor and supplies as our industry has ramped up spending, combined with growing resource nationalism, have resulted in widespread project delays.

In addition, OPEC has more successfully managed production levels. OPEC production cuts in 2007 were a key factor in reducing inventories and increasing prices. In addition, a number of OPEC members have experienced supply outages in recent years that continue to affect production levels, beginning with the PDVSA strike in late 2002 and including the Iraq war and civil unrest in Nigeria.

In addition to current fundamentals, changing expectations about the future have also affected oil prices. Many observers feel that geopolitical risks to oil supply have increased in recent years. Expectations of rising costs (including taxes) as well as policy changes in oil-producing countries that constrain the industry's development opportunities have bolstered long-term price expectations.

At the same time, a variety of factors have resulted in growing interest among financial investors in oil and other commodities. Recently, investors have responded to fears about a US economic downturn and a weakening dollar by seeking safety in oil and other stores of value, such as gold.

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[2] Venezuela: NY Times 29 Oct 07; Iran: Yahoo News 17 Mar 08

All of these factors have increased the price of oil.

The capacity for energy companies to respond with more supply has been constrained by several factors:

- The project development capacity of the global energy industry atrophied in the 1990s after years of low prices. Accumulating new specialized labor and equipment takes time and is expensive.
- Marshalling sufficient labor, materials, and equipment has been slowed by competition for resources from other industries that also took part in the rapid global economic expansion earlier this decade. The shortage of workers with relevant skills in the sciences is a particular concern.
- Finally, governments have limited the ability of companies to respond by limiting access to resources and raising the cost of doing business through new taxes and greater government regulation.

Given the labor and equipment capacity constraints, companies can and do continue bidding for a limited number of resources (drill ships, platforms, supply and heavy lift vessels) needed to produce oil. This has raised the cost of producing oil in the US and around the world.

What are the impacts of high oil prices?

Both producers and consumers are responding to higher prices. Our industry is growing investment rapidly: Official DOE data shows that US onshore Lower48 production rose in 2006 and 2007—the first increases since 1985. More broadly, non-OPEC supply continues to increase, driven by new investments in deepwater production, heavy oil, and biofuels. Consumers are also responding: Despite above average economic growth, global oil consumption growth was below average in 2006 and 2007.

However, medium-term fundamentals continue to look supportive of a high crude oil price. It appears unlikely that the outlook for supply and demand will result in a massive build-up of OPEC spare capacity as was seen prior to the price collapse in the mid-1980s.

Oil has always been—and will remain—a cyclical commodity. Lead times for capital-intensive projects are long—it can take upwards of a decade to develop a deepwater oilfield, and (on the demand side) 15 years to turn over the vehicle fleet. It is reasonable to expect that prices will again experience a downside of the cycle...at some point. At the same time, a number of factors—such as rising taxes, more costly forms of production, and difficulty accessing reserves—suggest that prices will remain above previous lows in any future downturn.

How does oil price influence gasoline price?

As shown in Exhibit 5, gasoline and diesel product price trends virtually mirror those of crude oil over the last 6-year period. However, examining recent price movements reveals that for the period of January 1 through March 14, 2008 gasoline price increases have lagged those experienced in the crude oil market (Exhibit 6, API, and NYMEX)

Exhibit 7 graphically represents the components that make up the cost of a gallon gasoline:

- The biggest single component of retail gasoline prices is the cost of the raw material used to produce gasoline - crude oil. Crude oil alone makes up 58 percent of pump prices (API, 2007 EIA data).
- Another major factor in gasoline prices is federal, state and local taxes, which account for 15 percent of the cost (API, 2007 EIA data). The nationwide average for gasoline taxes is currently almost 46 cents per gallon.
- Refining the crude oil into gasoline accounts for 17 percent of the retail price (API, 2007 EIA data). Refining costs can be affected by several factors:

  - U.S. refineries customarily reduce production each spring for routine maintenance before the heavy summer driving season.
  - Costs to comply with various government fuel regulations
- The remaining 10 percent of the cost of gasoline is the cost of distribution and retailing (API, 2007 EIA data).

Service stations may sell gasoline from a major oil company, but about 95% of stations are operated by independent business people who determine their own prices, which include a margin to pay for their cost of doing business and to provide a profit (although a profit can't always be assured).

Retailers base pricing on a variety of factors including the station's location and size, and such expenses as delivery costs, taxes, and contractual obligations to suppliers. Retailers also react to the prices charged by competing stations. If a station prices its gasoline too high compared to competitors, customers may take their business to a station with lower prices. If a station loses enough volume, it may then reduce prices to attract customers.

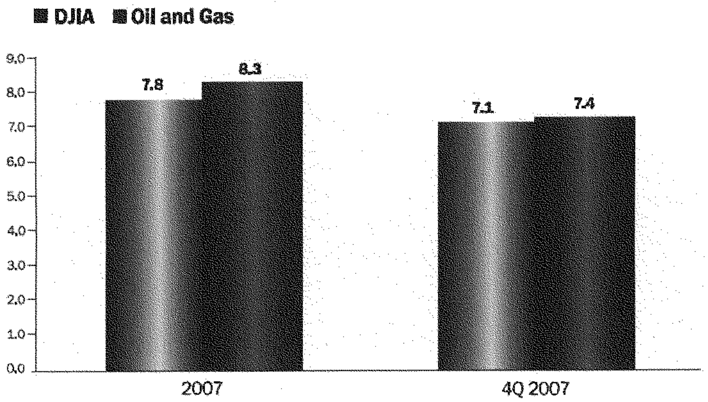
A station's retail price also typically reflects the cost to replace the gasoline currently in its tanks. If the station doesn't generate enough cash to buy its next delivery, the retailer would be using debt to finance that purchase.

What's next?

As I stated earlier, the US faces energy challenges today because of policies, market dynamics and decisions of the last few decades. Our focus should be to improve the situation and to lay the groundwork necessary to create a secure new energy future. We believe US interests are served by a strong energy industry enhancing US economic growth and enabling successful companies to better compete in the world economy.

It is my commitment to pursue policies and investments that will enhance oil and gas supplies, produce more motor fuels and begin to make the transition to a lower carbon future. I would like Congress to partner with us in this journey?

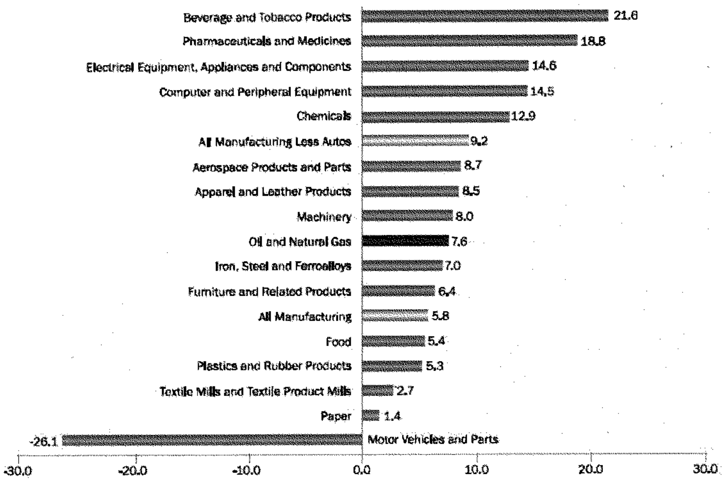
Earnings of Dow Jones Industrial Average (DJIA) Companies and Oil and Gas Companies
(net income divided by revenue)



The information contained in this document is based on publicly available information. The companies included in these documents are based on the Dow Jones Industrial companies. However any reference to Dow Jones is for informational purposes only and should not be construed as an affiliation with, sponsorship of, or endorsement of the information or documents in which the Dow Jones name is referenced.

The fourth-quarter and full-year 2007 earnings for the oil and natural gas industry are very large because the companies are very large. But the earnings are not out of line when they are compared with the earnings rate of other Dow Jones Industrial Average companies by measuring the cents earned for every dollar of revenue. In fact, the average earnings rate for the Dow Jones companies is only slightly below the earnings rate for the oil and gas industry. And there are other industries that do far better than oil and gas, including pharmaceuticals, computers and chemicals.

2007 Third Quarter Earnings by Industry (net income/sales)



Sources: Based on company filings with the federal government as reported by U.S. Census Bureau and *Oil Daily*.

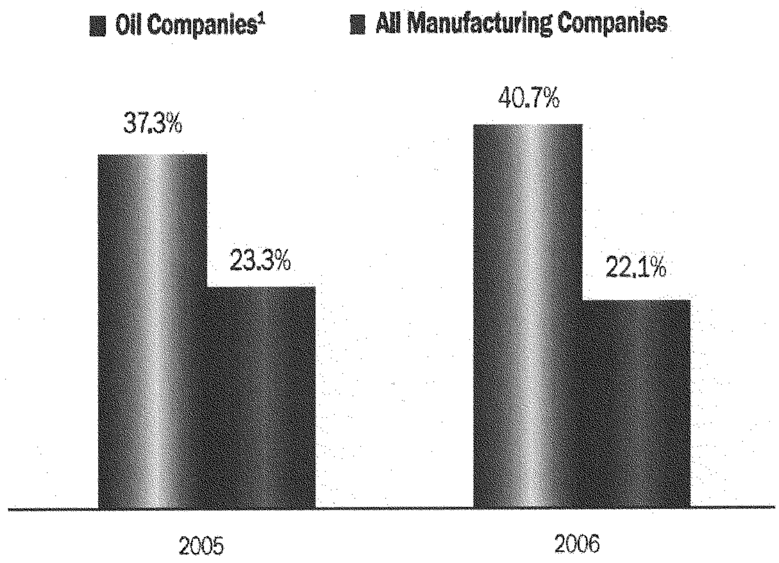
It may seem surprising that oil and natural gas earnings are typically in line with the average of other major U.S. manufacturing industries. This fact is not well-understood, however, in part because reports usually focus on only half the story—the profits earned.

Profits reflect the size of an industry, but they're not necessarily a good reflection of financial performance.

Profit margins, or earnings per dollar of sales (measured as net income divided by sales), provides one useful way to compare financial performance among industries of all sizes.

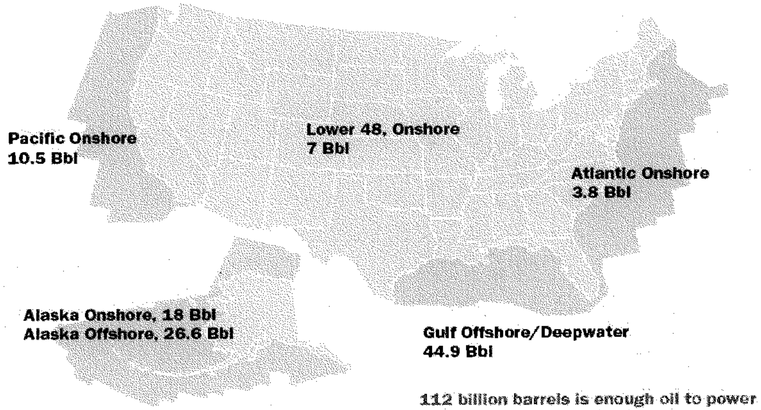
The latest published data for the third quarter of 2007 shows the oil and natural gas industry earned 7.6 cents for every dollar of sales compared to 5.8 cents for all U.S. manufacturing and 9.2 cents for U.S. manufacturing, excluding the financially challenged auto industry.

Income Taxes as Share of Net Income Before Income Taxes



Source: EIA, *Performance Profiles of Major Energy Producers*

U.S. Crude Oil Resources (Undiscovered Technically Recoverable Federal Resources)



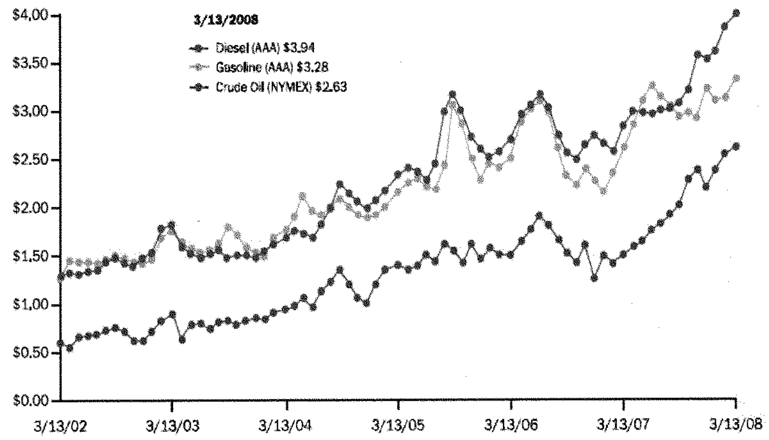
112 billion barrels is enough oil to power over 60 million cars for 60 years.

Source: MMS, USGS, and API calculations

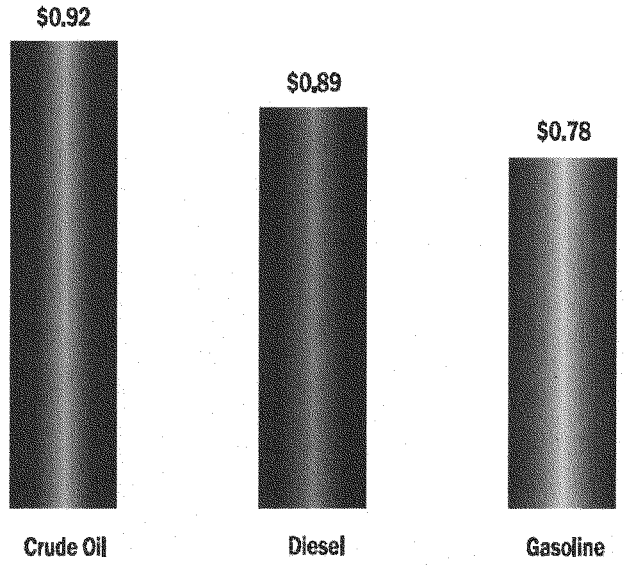
Our nation's energy security requires policies that do not disadvantage the investor-owned oil companies, but rather enables them to be competitive in the global marketplace. Our nation needs policies that promote greater supplies of oil and natural gas, not policies that hinder our industry's ability to provide American consumers the energy they demand and need. We have abundant volumes of oil and natural gas resources beneath federal lands and coastal waters, but the bulk of these resources have been placed off-limits to development.

For example, according to federal government estimates, there is enough oil in these areas to power more than 60 million cars for 60 years.

Diesel, Gasoline and Crude Prices

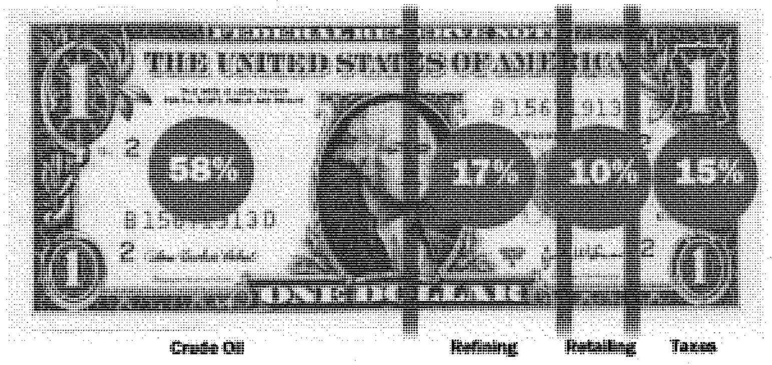


Average Price Increases Year to Date (cents per gallon) – **January 1 to March 14**



Source: NYMEX

What consumers are paying for at the gasoline pump



8.3% Earnings*

Source: Average of gasoline components from January through December 2007 as reported by EIA.
*Earnings differ by company. Figure represents average 2007 industry earnings for every dollar of sales.

The biggest single component of retail gasoline prices is the cost of the raw material used to produce gasoline—crude oil. For example in 2007, crude oil alone makes up 58 percent of pump prices. Refining made the crude oil into gasoline accounted for 17 percent of the retail price. Retailing added another 10 percent to the retail price of gasoline. Taxes accounted for 15 percent of the price of gasoline.

The CHAIRMAN. Thank you, Mr. Malone, very much, and that completes the time for opening statements from our witnesses.

And now we will turn to recognize members of the Committee for questions of the panel. The Chair will recognize himself for five minutes for that purpose.

Mr. Simon, last year Exxon Mobil reported $40 billion in profits, $28 billion in stock buy-backs, $7.5 billion in dividends and executive compensation, but all I can really find is no more than a commitment of $100 million in investment in renewables over the next ten years. Why is that, Mr. Simon? Why is your company not investing in renewables?

Mr. SIMON. Well, thank you, Mr. Chairman, for giving me the opportunity to address the area of alternative fuel. When you go back to the year 2000–2001, we as a corporation recognized that we had a huge challenge in front of us not only as a corporation, but as an industry in meeting a significant growth in energy requirements, estimated about 40 percent in the year 2030 compared to 2005, while still managing the risks associated with climate change as driven by the increase in greenhouse gas emissions.

At that time we looked at every component, every facet of alternative energy. We had our best and brightest minds, the scientists and engineers of the highest caliber in our corporation look at it on a fundamental basis. We looked at it all the way from production, on the one hand, all the way through consumption, on the other. We called a well to wheels analysis. We looked at it on an energy basis, on the energy balance.

The CHAIRMAN. How much have you invested in renewable energy, Mr. Simon, for 2008? What is your budget for renewable energy at Exxon Mobil.

Mr. SIMON. And I will get to that, Mr. Chairman.

The CHAIRMAN. I only have five minutes. It is important for us to get it out on the table. What is the investment in renewable energy, please?

Mr. SIMON. Recognizing that we needed to do something of a great magnitude, the current generation of fossil fuels do not work. What we did was we said we needed the best and brightest minds from all walks of life, and we initiated the global climate and energy project at Stanford University, which is about——

The CHAIRMAN. And how much money are you paying for that?

Mr. SIMON [continuing]. A $100 million investment over——

The CHAIRMAN. One hundred million dollars, but you made $40 billion last year.

Mr. SIMON. Mr. Chairman, putting more money into something does not necessarily equal progress.

The CHAIRMAN. Well, Shell is putting money into wind. BP is putting money into renewables, and we are not talking about 100 million over ten years. We are talking about billions of dollars which are being invested. Why is Exxon Mobil resisting the renewable revolution that is being embraced by other companies even in the oil and gas sector?

Mr. SIMON. Our analysis is that we are not going to be able to meet the challenge that you would like to meet and I would like to meet with current generation. That is our assessment. We need to leapfrog current generation technology. We need to have breakthroughs that are world changing, and that is what the objective of our global climate and energy project is at Stanford University. We have 40 breakthrough programs underway looking at every aspect of renewables.

We are looking wind. I mean solar. We are looking at biofuels, biomass.

The CHAIRMAN. We do not have time, Mr. Simon. Okay? We have got people you heard in my opening statement. For the poorest 20 percent in America it is now ten percent of their income going to paying their gasoline bill. So as these consumers are at the pump being tipped upside down and having money shaken out of their pocket, your message to them is that you cannot do anything for them, that you are about to begin a partnership to think about what you are going to do about a renewable energy agenda, and that is not going to send any message that we are going to put pressure on OPEC that we are about to change business in our country.

Mr. SIMON. Well, if we are going to have a kind of impact that you and I want longer term, it is going to take breakthroughs, and that is what we are trying to do there.

That does not say that we cannot do something to try to address the price at the pump today. About 80 percent of that price or 70 percent of that price is crude oil. What can we do there? One thing, we can moderate demand in terms of the transportation sector.

The CHAIRMAN. But you cannot have it both ways, Mr. Simon. You cannot, on the one hand, be nickel and diming renewables at Exxon Mobil and at the same time be recording $40 billion worth of profits and simultaneously fighting our efforts to move over the billions of dollars into the research in renewables which this country needs to break its dependence on imported oil. You cannot do that, Mr. Simon.

Exxon should make a commitment that they are going to put ten percent of their profits into renewables so that America has a comprehensive strategy to fight that dependence upon imported oil. Are you willing to make that kind of a commitment?

Mr. SIMON. Mr. Chairman, we continue to look at that area. If we identify an area where we think it can have the impact that you are alluding to, we will do that, but we have studied all forms, even anticipating some improvements, and the current technologies just do not have an impact, any kind of appreciable impact on this challenge that we are trying to meeting.

The CHAIRMAN. Mr. Simon, that is just going to be a continuation of a policy of tax breaks for the oil companies and tough breaks for consumers at the pump, and that just does not work.

OPEC has us over a barrel, and you are saying you are going to study the issue for another ten years, and with all due respect to Stanford, you have competitors here on this panel who are already investing in multi-billion dollar strategies in alternative energy, and I just think that it is time to move to this new agenda for the sake of our country and for the consuming public that really does feel as they have been short changed in terms of protecting them against what looks like to be a devastating, long-term prospect of paying $3.29, $4.29 and more at the pump for the indefinite future.

My time has expired. I turn to recognize the gentleman from Wisconsin, Mr. Sensenbrenner.

Mr. SENSENBRENNER. Thank you very much, Mr. Chairman.

One of the things that I learned when I got to Congress is that we do not have the power here to repeal the law of supply and demand. Obviously demand is up, particularly as a result of the increased demand in emerging economies like China and India. Supply is restricted, partly due to the fact that we have not been able to build new refineries in this country to increase supplies to consumer, and then as a result of our low interest policy, which we need to prevent a complete collapse of the housing market, you see the value of the dollar tanking on overseas markets, and the OPEC nations who do sell us oil are not going to want to get paid in cheaper dollars.

Now, all of that on the table and not too much we are able to do about it either in Congress or on your side of the table, what do each of the five of you think is the single most important policy that Congress can make to increase supply and thus take the pinch off of higher prices?

You can start, Mr. Simon.

Mr. SIMON. Well, Congressman, I do not think there is any silver bullet here.

Mr. SENSENBRENNER. Well, we know that, but I am asking you to prioritize, and I have got three and a half minutes left and you have got four colleagues that want to speak.

Mr. SIMON. To me it would be to open access to supplies that are currently off limits. We have 31 billion barrels, 105 trillion cubic feet of natural gas. That is enough to power ten million automobiles and heat 15 million homes here in the United States for over 100 years.

Mr. SENSENBRENNER. Okay. Mr. Hofmeister.

Mr. HOFMEISTER. I think the Congress should look at short-term, medium-term and long-term solutions in a comprehensive strategy that would take into account everything from more access to the new and developing technologies of the future. If we do not look at it short term, medium term, long term, we will suffer enormously in the next several years from a shortage, a continuing shortage of hydrocarbons.

Mr. SENSENBRENNER. Mr. Robertson.

Mr. ROBERTSON. Well, I think there are a lot of things that the Congress can do. I think, you know, starting to leave an efficiency message to the American people is the first most important thing, but after that, I think we need access to all kinds of energy supplies, renewables and oil and gas.

The single biggest thing I think would be to open up the 85 percent of the offshore acreage in the United States that is currently unattainable. I think it is unrealistic to ask the rest of the world to open up their areas without us doing the same ourselves.

Mr. SENSENBRENNER. Mr. Lowe.

Mr. LOWE. Yes, we need to support all forms of energy, but particularly as my colleagues have said, we need more access here in the United States.

Mr. SENSENBRENNER. Mr. Malone.

Mr. MALONE. Congressman, access is number one, but I would also emphasize the huge potential that sits north of us in Canada, as we have the Saudi Arabia of North America sitting there ready to provide us with needed energy.

Mr. SENSENBRENNER. Okay. Now, that all being said, I guess the common thread that I have heard from each of you is that we need more access, and you have all alluded to where the access is.

If you got the access, would you have the refining capacity to be able to increase the supply to the consumer and thus at least take the pressure off of ever increasing prices? We have not built a new refinery in this country in 30 or 35 years. So if you have the access but you cannot refine it, how do you get the product to the consumers at at least the same price if not a lower price?

Why don't we start with Mr. Malone?

Mr. MALONE. Access, for example, two of our projects are to expand our existing refineries with the use of access being allowed on Canadian heavy crude. Both of those, that will result in something like 2.2 to 2.5 million gallons a day more gasoline. So physically we can expand our refineries, which we have been doing for years.

Mr. SENSENBRENNER. Mr. Lowe.

Mr. LOWE. Yes, we are spending billions of dollars to expand not only the capacity of our refineries, but also the capability of our refineries to run these heavier crudes, but we have encountered significant difficulties. Even though we are trying to increase capacity and produce cleaner fuels, we have encountered significant difficulty in permitting these projects.

Mr. SENSENBRENNER. Mr. Robertson.

Mr. ROBERTSON. The U.S. use of oil in the last few years has been about flat. So if we produce more oil and gas in the United States, we would have to import less. We have the refining capacity in the United States to deal with the market today, I think. So I think the issue is around if you produce more oil in the United States, more on the world market, prices directionally are lower. We import less.

Mr. SENSENBRENNER. Mr. Hofmeister.

Mr. HOFMEISTER. I mentioned the $7 billion investment that is currently ongoing in Port Arthur, Texas. This will more than double the size of a refinery and take it to over 600,000 barrels a day, one of the world's largest. I think we have the refining capacity to meet future demand.

Mr. SENSENBRENNER. My time is up, but can I ask Mr. Simon to put his two cents worth in?

Mr. SIMON. We have expanded our capacity at a rate 50 percent higher than industry. We do not think we will have any issues in terms of continuing to expand our existing capacity sufficient to meet demand in the future.

Mr. SENSENBRENNER. Thank you.

The CHAIRMAN. The gentleman's time has expired. The Chair recognizes the gentleman from Oregon, Mr. Blumenauer.

Mr. BLUMENAUER. Thank you, Mr. Chairman.

I would just make a request. Mr. Simon, not now because you wouldn't have time to explain it and I would like to see it on paper, if you could just explain? Have someone submit to the Committee the accounting assumptions that are used to explain how you pay more in taxes than you earn in the United States, what assumptions you are making about downstream business versus upstream profits overseas would be very useful for me.

I appreciate the couple of references that were made to the demand side of the equation. Mr. Hofmeister, I don't think you got to it in your testimony on page 9, but you talked about land use and demand management and how people use the automobile, notions about some very specific things that we need to think about in terms of 17 boutique. I mean, these are important things for us to hear.

But there are two points, I guess, that I would like to just zero in on. There are implications here that if we just opened up all our sensitive areas to oil exploration, that somehow we wouldn't be in the fix that we are in today. But your testimony referenced the fact that we are five percent of the world's population with three percent of the world's proven reserves. And we are consuming 25 percent of the world's oil supply.

Do any of you think any circumstance that we wouldn't be in a serious situation today given those facts and that we are going to need to change it in the future? Anybody think this is sustainable?

Mr. ROBERTSON. Well, I think in my testimony, I think I said it is not sustainable.

Mr. BLUMENAUER. Does anybody think the current situation is sustainable? Thank you.

Mr. SIMON. Well, I certainly feel that we are going to be able to meet increased requirements given access and given the opportunity to do so.

Mr. BLUMENAUER. Which is different than the current situation of being sustainable with 25 percent. Is there any reason that any of you think that American technology, conservation, demand management, that over the next 10 or 15 years, we can't at least come close to what other countries are doing in western Europe, in Japan? Is there any reason we can't come close to reducing our per capita energy utilization over the next 10 or 15 years with those mechanisms?

Mr. ROBERTSON. I think we can do an awful lot on demand management. I think I said that was the most important thing that we can do.

Mr. BLUMENAUER. But can we catch up with the Japanese——

Mr. ROBERTSON. Yes.

Mr. BLUMENAUER [continuing]. And the Europeans over the next 10 or 15 years?

Mr. ROBERTSON. Yes, I think absolutely. We have a company called Chevron Energy Solutions that delivers energy efficiency services to other public agencies and to companies. They have done 800 projects over the last few years. Many of them involved putting in solar panels, putting in fuel cells, putting in whatever it takes that particular facility to reach their energy use.

Mr. BLUMENAUER. Mr. Robertson, I appreciate your clarification. I think that is very important. I appreciated what a number of you said in terms of diversifying and to being truly global energy companies.

Mr. ROBERTSON. But there is——

Mr. BLUMENAUER. Now, I would like——

Mr. ROBERTSON. And the energy cost is 30 percent on average of the places they have been.

Mr. BLUMENAUER. What I would like to do is just with my remaining seconds is to clarify on the last point because you, some of you more aggressively than others, understand that the future is going to be weighted in significant ways towards renewable energies, towards solar, towards—some of you are doing geothermal now—biofuels, wind.

I am curious at what point the mature part of your business, the oil production, which didn't even have the manufacturing benefit up until 2004, at what point it is mature enough that we can focus the subsidy on areas of the emerging energy business and, in fact, many of you are involved with that appear to need it more, like wind and like solar. At what point do we make that switchover?

Mr. HOFMEISTER. I think in the first instance, Congressman, your time frame of 10 to 15 years is too short. I think there is too much to be done to change behaviors, technology, and to refleet America, so to speak.

We don't have the benefits of the dense housing that exists in other parts of the world. So we have long commutes. We don't have the benefits of mass transit systems.

But, coming to your more recent question, I think that the issue that is most troubling in terms of the 199 withdrawal is a fact that the Congress is punishing 5 companies by name. I think that there is a——

Mr. BLUMENAUER. My point is, at what point do you no longer need it and it can be shifted to areas that do?

Mr. HOFMEISTER. You know, we are mature already. We are successful as a company. I testified two years ago that we are not asking for a——

Mr. BLUMENAUER. And wind and solar are not yet as mature?

Mr. HOFMEISTER. Wind and solar have lots of obstacles to overcome, even though we are investing today and moving as rapidly as we can. There is not enough turbine manufacturing. There are not enough transmission lines to make wind viable in terms of rapid growth.

Mr. BLUMENAUER. Thank you. I see my time has expired. I appreciate your clarification.

Mr. Chairman, I appreciate your indulgence. I guess my only concern is that we ought to be serious about taking this as something in terms of the time frame being too long. I think 10 to 15 years may be actually that we don't have that much time as gasoline goes to $5 and $10 a gallon, a supply becomes more tenuous, as the global warming reality sets in.

And I suspect with your help and with a couple of reauthorization bills and a national strategy for infrastructure, I think we could put these pieces together sooner. I don't know that we have a choice.

Thank you, Mr. Chairman.

The CHAIRMAN. The gentleman's time has expired.

The Chair recognizes the gentleman from Arizona, Mr. Shadegg.

Mr. SHADEGG. Thank you, Mr. Chairman.

Gentlemen, this is a hearing structured to deliver a fair amount of criticism to you. It seems Congress is good at that and not necessarily good at pointing a finger at itself.

I want to ask you about a policy that this Congress enacted which I think deserves some criticism itself. It is my understanding that as a result of a loophole in the U.S. Tax Code, we have created a policy now recognized as splash and dash, where we created an incentive to produce biodiesel and enacted policies which provide that if you add as little as one gallon of biodiesel to 99 gallons of diesel produced by standard means and then you export that fuel, the U.S. government will provide you a dollar a gallon subsidy. This has become known as splash and dash.

It has cost the American taxpayers, I believe, $30 million. Several attempts have been made to repeal this by the Congress in the last few years. None have done so. I understand Senator Schumer is working on a repeal.

I would like to just begin by asking each of you if you are familiar with that and if you think there is any justification for that kind of a waste of American taxpayer dollars.

Mr. SIMON. Congressman, our position is that we do not need and should not have incentives to encourage us in the renewables area. If there is an opportunity there and it will make sense, it ought to stand on its own. And free enterprise will go after it.

Mr. SHADEGG. Are any of you aware of this splash and dash practice, where biodiesel is added?

Mr. ROBERTSON. Yes.

Mr. SHADEGG. Yes, sir, Mr. Robertson?

Mr. ROBERTSON. I am aware of it. I think you characterized it probably right. We haven't taken advantage of it and don't need it.

Mr. SHADEGG. My characterization is quite accurate, then?

Mr. ROBERTSON. It is pretty accurate, yes.

Mr. SHADEGG. And it is costing the American taxpayers as a result of this subsidy. And, as I understand it, the diesel fuel is actually then being exported. So the——

Mr. ROBERTSON. I don't know. I can't confirm the number that you said in terms of the millions of dollars, but I think your characterization of it as a way to export and take advantage of credit is right.

Mr. SHADEGG. I certainly hope that that kind of a loophole can be closed very quickly and that it makes no sense for us to be subsidizing foreign use of our diesel fuel to encourage the production of biofuels here in the United States. And it is my understanding that it has that economic impact. It is a dollar per gallon by simply adding one gallon of biodiesel to 99 gallons of regular diesel.

Mr. Simon, can you tell me what percentage of the world's ten biggest oil companies or natural gas companies are owned or operated by foreign governments?

Mr. SIMON. Well, if you look at the top companies, only about 2 of the top 13, as I recall, are national oil companies. And the rest of them are international oil companies.

Mr. SHADEGG. And do you know what percentage of the world's proven reserves U.S. oil companies control?

Mr. SIMON. Well, I know what it is in terms of national oil companies. It is about six percent. I am sorry. The international companies is six percent. National oil companies is about 80 percent.

Mr. SHADEGG. Mr. Hofmeister, you testified that U.S. oil production has declined, I believe you said, over the last—I am not sure if you said decade. While our demand has gone up, our production has gone down.

Mr. Robertson, you explained that we have enacted increasing policies to restrict access to fuel supplies here. And you expressed concern about the rest of the world being asked to produce more energy supplies while we are restricting access to energy supplies here.

One of my colleagues up here said, well, perhaps you were suggesting that the answer is that we be allowed to drill in every sensitive area. I suspect there are areas that are less sensitive than others. And I suspect that or I would like to know, is there a correlation between the number of areas that have been reserved or locked off over the last decade and the decline in production and are there areas that you could point to where we could be exploring, either of you or any of you, where we could be exploring for reserves or using reserves that are there to increase production here in the United States without doing environmental damage?

Mr. ROBERTSON. Well, I mean, you know, one of the things that I would point out is that the offshore, most of the offshore, in the United States has not been looked at with modern technology in many, many, many years. It was really 1980s and 1970s technology, seismic technology, that looked at that.

So the first thing that I think would make sense to do—and the government, frankly, could do this—is sponsor a seismic survey of the offshore, of the entire continental shelf of the United States. And then at least you would be talking about facts.

You would know what was prospective and what wasn't perspective. You could look at the areas that were environmentally sensitive and the areas that aren't environmentally sensitive. And you could zero in and be debating on real information, as opposed to worrying about the whole offshore, because it is pretty clear that there are going to be some areas that are prospective for drilling and there are going to be some areas that aren't.

So at least you could narrow the playing field, it seems to me, very dramatically and figure out where the likelihood of America's opportunity is.

Mr. SHADEGG. And do you believe that is substantial?

Mr. ROBERTSON. I believe it is substantial, very substantial, yes.

Mr. SIMON. Mr. Hofmeister.

Mr. HOFMEISTER. Absolutely. I think knowing what we know from past surveys, I think the API estimates there are more than 100 billion barrels of reserves that are not coming from what some people might term sensitive areas. These are outer continental shelf deposits that have been there for geological areas.

And not having had access for some 30 years, we have seen this steady increase in imports and steady decline in American production. We have geared our exploration and production to around the world, rather than the United States.

Mr. SHADEGG. I thank you for your testimony. I assume technology has improved in that 30 years in terms of protecting the environment.

The CHAIRMAN. The gentleman's time has expired.

The Chair recognizes the gentleman from Washington State, Mr. Inslee.

Mr. INSLEE. Thank you.

First off, we need to say something good about the industry here. One point of this hearing, I want to congratulate BP for meeting their Kyoto CO_2 reduction targets of their internal operations within, I think, three or four years, showing that this can be done. It is a good example for the rest of us.

I want to ask,—this is a question to all of you—did you or any of your associates participate in the secret Vice President Dick Cheney Energy Task Force in 2001?

Mr. ROBERTSON. We did not.

Mr. HOFMEISTER. I testified previously the answer is no.

Mr. SIMON. No.

Mr. MALONE. Yes.

Mr. INSLEE. And, Mr. Malone, could you make your documents related to that, secret meetings, available to the Committee?

Mr. MALONE. Yes, sir.

Mr. INSLEE. Thank you. We would make that request.

Mr. Simon, listening to your testimony makes me even more convinced that we need to act to create an incentive for decision-makers and industry to really make real investments in the clean energy revolution, rather than relatively small ones.

And the reason I say that is that listening to you, as far as I can tell, you are spending less than half a percent of your gross revenues on clean energy research. Is that right?

Mr. SIMON. It would be a very modest amount. I would acknowledge that. But I would not acknowledge that we are not doing a lot to address greenhouse gas emissions.

Mr. INSLEE. Well, considering that we have to cut our greenhouse gas emissions 80 percent in this country below our levels by 2050, would you agree that if your company continues on its present course, it will fall several hundred orders of magnitude short of what we have to do to prevent cataclysmic global climate change?

Mr. SIMON. Well, the assumption there that that is required in order to do that, I would——

Mr. INSLEE. How is it going to happen? I mean, oil isn't going to, all of a sudden, become clean. We need to do the research to figure out these technologies.

Mr. SIMON. No, but the fact is that we are going to have oil and gas and coal. And it is going to constitute about 80 percent of the energy equation.

With that as a given, how do we then address and do what we can to mitigate greenhouse gas emissions with that being the case?

Mr. INSLEE. Would you agree with me, sir, that if Exxon continues on its present course of having less than one-half of one percent of its revenues associated with clean energy sources other than oil and gas, that the world is going to suffer significantly unless Exxon and its like changes its behavior?

Mr. SIMON. No, I don't agree with that. And I think we can do a lot more in terms of emitting greenhouse gas emissions by focusing on the areas that we are, transportation, efficiency improvements being one.

Mr. INSLEE. So if you don't put research dollars into it, is it going to come from the oil fairy somehow? These new technologies are going to show up?

Mr. SIMON. No.

Mr. INSLEE. We have got to put some real money in this, don't we?

Mr. SIMON. Given the fact that, again, we got oil and it is in our equation and it is going to be a significant factor, we are focusing on how do we make the use of that oil much more efficient.

Mr. INSLEE. Well, let me suggest—I hope that you will go take from this hearing a much more optimistic viewpoint of our capability.

You mentioned the money you are putting into Stanford. I was at Stanford last weekend talking to their scientists. And I was very excited by going over a report called a renewable energy solution to global warming presented by Mark Jacobson, Atmospheric Energy Program, Department of Civil and Environmental Engineering, Stanford University.

And what they concluded—and I will just read you a couple of sentences in the summary—"The U.S. could replace all on-road vehicles with battery electric vehicles powered by 71,000 to 122,000 5-megawatt wind turbines less than the 300,000 airplanes the U.S. produced during World War II. Wind battery electric vehicles could reduce U.S. carbon dioxide by 25.5 percent. Solar battery electric vehicles can reduce it by 23.4 percent."

Now, would you agree with me that this, a vision from Stanford, the folks that you are giving some money to, is one that the United States really needs and that with your pathetically small research budget we are not going to meet unless something changes?

Mr. SIMON. No, I don't agree with that, Congressman. And I would invite you to go look for yourself at what we are doing in a global climate and energy project. I think you would find it to be quite significant. It has long-term very significant impacts in terms of what it can do on the energy equation and greenhouse gas mitigation.

Mr. INSLEE. We actually did ask your company to give us the investments they were making in this, and you refused to give it to us. But you have helped us by telling us it is less than one-half percent.

Now, I can tell you that there are a lot of constituents that think that that is an inadequate contribution to the future of the planet Earth. And I just hope things change. And obviously we have got to change them by changing this tax policy.

Thank you.

The CHAIRMAN. The gentleman's time has expired.

The Chair recognizes the gentleman from Oregon, Mr. Walden.

Mr. WALDEN. Thank you very much, Mr. Chairman.

I just have to ask this question because I know if my constituents were here, they would ask it. With your record high profits, have you thought of lowering the price of gasoline with any of that?

I mean, I am a small business owner for 21 years. There is that margin where you don't have to charge quite as much if you are making a profit.

Mr. HOFMEISTER. Could I say something in favor of profits? Profits are what enable capital investments to increase the supply.

Mr. WALDEN. You are talking to a capitalist.

Mr. HOFMEISTER. Lowering our prices happens in many markets based upon local supply and demand. The prices go up. The prices go down. These prices are set at the street level in the local marketplaces where they come from.

The global price of crude, however, is the real issue. That is the real problem in the cost of gasoline. And the global price of crude will not go down unless the supply increases.

Mr. WALDEN. Or the demand goes down. And that is what I fear is happening in our country today. It is not that the demand is going down because of conservation. The demand is going down because our economy is taking a big hit. The people are having to make some really tough choices.

You have got the independent truckers today that are boycotting or striking to send a message. I mean, we are at a very, very perilous time in our economy right now.

I am not against profits. Don't get me wrong. Again, I am a small business owner for 21 years. I understand that it's important to make the next set of capital investments. I also understand the reinvestment can come to helping your consumers once in a while, too, in terms of price where that is appropriate.

Mr. Robertson, I have a question for you regarding ethanol. I understand that Chevron blends—about 40 percent of gasoline that you sell in the United States has ethanol in it. Can you speak to us about the volatility in price that has specifically been documents related to ethanol in that mix? Is that driving gas up or not?

Mr. ROBERTSON. I think ethanol prices have been pretty erratic here in the last couple of years. And they were——

Mr. WALDEN. Is your mike on, sir?

Mr. ROBERTSON. Yes, it is.

Mr. WALDEN. Okay.

Mr. ROBERTSON. Ethanol prices have been pretty volatile over the last couple of years, but I think it is a very small part, frankly, of the price of gasoline. I think it has been already testified 70 percent of the price of gasoline is crude oil, 15 percent of the price of gasoline is taxes.

So the balance, effectively, if you take today $100 oil and 42 gallons is $2.50, 2.50 a gallon is crude oil, add 40 cents for taxes, $2.90, there isn't much left. So I think, frankly, even though ethanol is about five percent of our gasoline, that volatility hasn't had that much of an effect.

Mr. WALDEN. Okay. I appreciate that. I used to chair the Forestry Subcommittee and have been very interested in your partnership with Weyerhaeuser in terms of biofuels. And I know my colleague from South Dakota and I both have been real interested in trying to correct a wrong in the energy bill that passed. It said woody biomass of federal forest lands or unless it has grown specifically for biomass, doesn't count toward renewable fuels standard, which seems sort of bizarre if we are serious about getting to the next generation of fuels.

Can you talk to us about any breakthroughs you are seeing on cellulosic development, where we can turn woody biomass into a fuel we can burn in our vehicles at an economic rate?

Mr. ROBERTSON. You know, I don't think I can tell you much about any new breaks. I mean, the JV with Weyerhaeuser is relatively new, although we have been working with them for about a year.

Mr. WALDEN. Right.

Mr. ROBERTSON. The thing that is important is they have got a huge amount of forestry, obviously, and timberland in the United States——

Mr. WALDEN. Right.

Mr. ROBERTSON [continuing]. And a lot of knowledge on chemistry of forest products. We have got a lot of knowledge on fuels and the chemistry of fuels. And we are pretty convinced that, working together, we can come up with something that we can create, make into a commercial scale project. But at the moment, it is really about technology and about trying to find the breakthrough.

We have also got a whole series of partnerships with universities: one in Georgia Tech, which deals with forest products; one in UC California, Davis because they have got different kinds of agricultural projects there; one in Texas, so different places, trying different kinds of feed stocks. But I can't report any breakthroughs yet. It is not that the science doesn't work. It is the scale, the scaling.

Mr. WALDEN. Right.

Mr. ROBERTSON. We have got the science in lots of places. We just——

Mr. WALDEN. I think it holds great promise, indeed.

Mr. ROBERTSON. Yes, I think it is great promise.

Mr. WALDEN. Mr. Malone, while you are here, I also serve on the Energy and Commerce Committee and the Oversight Investigation Subcommittee. And we did some oversight hearings on your pipe issue up in Alaska. Can you give us an update on the security of that piping system up there?

Mr. MALONE. Thank you, Congressman. I remember the hearings well.

Yes. Excellent progress. As you know, we said we would have it done in two years. Because we have to do it during the winter season, with our partners, the lines have now been replaced.

We are finishing up the last bit of it. It will be done on schedule, maybe even ahead of time. We actually have oil flowing through the one section of the new transit line.

Mr. WALDEN. And the last time I was in Alaska, there was a discussion about the end of the Prudhoe Bay oil because the amount it takes to come down the pipeline may get to a point where it is just not adequate to flow. Can you give us an update on the status of that and the effect to the market when that happens?

Mr. MALONE. Well, first of all, there are lots of opportunities. Again, there are several of us producing up there. But from our perspective, we see a 50-year future if we are able to move into some of the heavier oils and also the in-field enhancements that we have.

We originally thought we would recover somewhere around 25–30 percent of the oil. This field has the potential actually to recover 65 percent. So right now we are working as hard as we can to continue the flow from Prudhoe Bay.

Mr. WALDEN. Thank you. And thank you, Mr. Chairman, for your indulgence.

The CHAIRMAN. The gentleman's time has expired.

The Chair recognizes the gentleman from Connecticut, Mr. Larson.

Mr. LARSON. Thank you, Mr. Chairman. And thanks to all of the witnesses as well for your testimony.

I want to make an assumption. I think it is pretty broad but pretty clear that your primary responsibility, your primary fiduciary responsibility, is to the shareholders of your companies. And when you make decisions based in the free enterprise system and in the marketplace, it is based on results for the shareholders. Is that a fair assumption? Is there anyone who would disagree with that?

When we make decisions—and a lot of our decisions are policy decisions based on the citizens that we are sworn to serve. And there was a lot of testimony and very productive testimony. And thank you for that.

I want to get back to this whole issue of supply and demand. In my district, the independent Connecticut petroleum dealers' association is saying that whole system has gone amuck. The laws of supply and demand are not operating on the street, as you were alluding to, Mr. Hofmeister.

I understand in general what you are saying, but in the instance of particularly oil and gas, we have seen this speculation. We see people who do not either receive or store oil but are pushing paper forward and causing the artificial rise in price of oil.

Do you agree with the independent petroleum council or are they way off base here? Start with Mr. Simon. We will go right down the line.

Mr. SIMON. When you look at the fundamentals of our business, Congressman, the supply/demand fundamentals, our assessment would be the price should be somewhere around $50–55 a barrel. There is a disconnect.

To me, there are three factors that contribute to that. One is the monetary issue, the weaker dollars we have already talked about. The other is geopolitical risk. And the third, we believe, is speculation. And you could probably break that into three parts. And it is about 30 to 40 percent of——

Mr. LARSON. Would most of you agree with that assessment or would you alter your assessment? Most of you would agree with those three factors? I would agree with those three factors. What would you do about the——

Mr. ROBERTSON. I think the price of the dollar is part of it as well.

Mr. LARSON. Okay. What would you do about the speculators?

Mr. ROBERTSON. What would I do about—I mean——

Mr. MALONE. How do we get rid of the Jim Fisks and Jay Goulds of the crude oil? How do we stop this artificial influctuation of prices?

Mr. ROBERTSON. Well, I agree with what was just said, that the main things that I think are driving the price of oil are the huge demand in the world, the reduction in spare capacity in the world, the price of the dollar.

Mr. LARSON. Because of the economy, we have just witnessed that demand is lessening here. Hopefully through conservation, demand will lessen as well. And, yet, we see——

Mr. ROBERTSON. We are part of a world system. And the——

Mr. LARSON. We are part of a world system, but here in this country, we are responsible to our citizens. And how do we say? As I said at the outset, how do you turn to the lady who has to turn over an entire Social Security check to pay for her oil bill? That the laws of supply and demand are in effect?

How do we deal with the fact that people can in this system manipulate the price in such a manner that, even through all of your good efforts—and then it has us saying to you, in turn, "Hey, what do you need that tax cut—what are spending? What are we giving you a tax break of $107 billion for?"

People at Augie & Ray's in my hometown are asking that very question.

Mr. ROBERTSON. We have chosen by our policy to be dependent on oil from overseas. That is our choice. We chose not to develop our own resources in this country. That was our choice. And the fact of the matter is we are part of the world. We are part of the growing demand in the world. And we——

Mr. LARSON. As long as it is more profitable. What incentive is there for you to develop alternatives as long as it is profitable and you are able to get the rates that you are currently able to get? And if your sworn fiduciary responsibility is to provide the greatest return for your shareholder, geez, I don't know,——

Mr. ROBERTSON. We are spending a lot of——

Mr. LARSON [continuing]. But it seems to me like, hey, if I were one of your shareholders, I would be saying, "You know, they are not doing a bad job. I am getting a pretty good yield on my dollar here."

But if I am a citizen of this country, I am saying, "We are not making out so well here."

Mr. ROBERTSON. Our shareholders only get return if the customers are being satisfied with the product. If we don't sell a product that our customers want, that our shareholders are going to——

Mr. LARSON. This is a matter of customers not—they don't have a choice here. When it is between heating your home or freezing to death, that is not much of a choice. You know, when it comes down to whether or not you are able to get back and forth to work, that is not much of a choice.

Mr. ROBERTSON. Oh, I understand——

Mr. LARSON. It is what my grandfather says. Trust everyone but cut the cards. And somewhere in here, there is a disconnect. We need your help in trying to fix this disconnect.

Mr. Stupak was here, who left, also has proposals that are talking about the manipulation of the market. I guess——

Mr. ROBERTSON. We are doing our damnedest to fix this. We are spending as much money as our company can with our human people that we have and the infrastructure that exists. We are spending as much as we can to produce energy for the people in this country and the people in the world. We don't know how to——

Mr. LARSON. My time is up, but I would be interested if you, all of you, could in writing—I would love to hear your opinions on what you would do to the speculative side of this market that distorts the entire market and your integrity as well.

The CHAIRMAN. The gentleman's time has expired.

The Chair recognizes the gentle lady from Michigan, Mrs. Miller.

Mrs. MILLER. Thank you, Mr. Chairman.

And I did mention in my opening statement and I would then agree with some of the comments that have been made by some of our witnesses here that we have made a choice as a nation, unfortunately in my estimation, not to advantage ourselves of much of our own energy supplies. And that is to our own disadvantage, I think.

But, however, we have made that choice as a nation. But, as has been mentioned, we are in a global market for energy. And so my first question would be in regards to supply.

Being from Michigan, a border state, we look across to our wonderful neighbors in Canada. And we see all of the oil sands that are there. One of you mentioned about the oil sands.

I am just wondering, what is the actual percentage of our foreign supply that we get to the United States actually comes from Canada now? In regards to the oil sand, could any of you tell me generally what you think the potential might be there for an increase in the supply to us from Canada? And I also have an interest—I mean, I have heard, for instance, that China is up there trying to lock down a contract for as much as they can of the oil sands.

And then also in regards to the process of refining, I believe it is Shell that is going to be about 20 miles from my district, actually, on the Canadian side was building a very large refinery for the oil sands, the Canadian oil sands. I am not sure who I am directing this to.

Mr. Lowe.

Mr. LOWE. ConocoPhillips is the largest landholder in the Canadian oil sands. And we have a number of different projects——

The CHAIRMAN. Is your microphone on, Mr. Lowe?

Mr. LOWE. Yes. Sorry.

The CHAIRMAN. If you could move in a little bit closer, please?

Mr. LOWE. ConocoPhillips is the largest landholder in the Canadian oil sands. We have a number of very good projects, each multi-billion-dollar projects, that we are advancing. And we believe that ultimately the Canadian oil sands can supply about 20 percent of the U.S.'s oil needs.

But we are going to have to develop our refining infrastructure and our pipeline infrastructure to make sure we can get that crude into our refineries and make sure our refineries can process the heavier crude.

Mrs. MILLER. Twenty percent? What is it currently how much, approximate percentage?

Mr. LOWE. It is relatively small.

Mrs. MILLER. I see.

Mr. ROBERTSON. I will make a comment. The U.S. uses about 20, a little over 20, million barrels a day of oil. Today there are about 2 and a half million barrels a day of oil comes from Canada.

So our largest importer, our largest imports of oil, come from Canada. Second largest come from Mexico. But the oil sands, as was described, could potentially be two or three million barrels a day, maybe higher than that. So they could double the input from Canada and be 10 percent or 15 or 20 percent of U.S. demand.

Mrs. MILLER. When do you see that happening? I mean, what time frame? Two years?

Mr. ROBERTSON. No, no.

Mrs. MILLER. A hundred years?

Mr. ROBERTSON. Ten, 15, 20 years.

Mrs. MILLER. I see. Mr. Malone.

Mr. ROBERTSON. It is going to build up over time.

Mr. MALONE. I just wanted to add that, you know, we have two Midwest refineries, one in Indiana, one in Ohio, that through either joint ventures now or through supply agreements, we are going to expand both those refineries to take on a significant, essentially completely have a Canadian crude for the Midwest, again including your state, it is somewhere in the area of 2.6 million gallons more a day. So the supply is there.

Mr. HOFMEISTER. I think a point should be made that the oil sands are successful because of a national energy strategy that was developed by our neighbor to the north. We have the same opportunity in this country to develop a national energy strategy.

The United States is blessed with more than a trillion barrels of potentially recoverable resource in the oil shale of Colorado, Utah, and Wyoming.

We have, Shell has, been in that region for more than 20 years testing, experimenting, environmentally sound ways to potentially extract that resource. And we do not see support coming forward to make that a reality in terms of national policy. And it might be something for Congress to consider.

Mrs. MILLER. Congress doesn't always do well in national policy. And, Mr. Hofmeister, I know in your testimony, you said you applauded the higher CAFE standards. But the domestic auto industry, my personal observations are, we are going to end up bankrupting the domestic auto industry because of the mandates that we put on it. But I appreciate what you have said there.

I only have 30 seconds left. What about China? We keep hearing about China up there contracting for the oil sands. Does anybody have any comment on that and what is happening there that might shut us out of the supply?

Mr. ROBERTSON. I don't see they are going to shut us out of the supply. I mean, China is in many ways just like the United States. They are competing in the world for energy supplies. We are competing with them. They are investing in projects around the world, just like we are.

They are investing in Canadian projects, like we are. But I don't think there is any shutout by Canada. In fact, most of the oil in Canada mostly like is going to come south to the United States.

Mr. SIMON. I would agree with that. I think we also have to be careful about passing legislation here that would cut us off from that supply of heavy tar sands and heavy oil from Canada, which I think is a real issue that Congress needs to address.

Mrs. MILLER. Thank you, Mr. Chairman.

The CHAIRMAN. The gentlelady's time has expired.

The Chair recognizes the gentleman from Missouri, Mr. Cleaver.

Mr. CLEAVER. Thank you, Mr. Chairman. I am going to try to ask short questions and so I can get short answers in my time.

My father worked all of his life. He never earned more than $25,000 a year. And there were years that he actually worked three jobs, most of the time just two. He sent four children to college. He is 86 years old.

There will be people like my father all over the country. And I will have some of them at a meeting next Saturday when I do my monthly coffee with the congressmen.

Mr. Simon, what can I say to them to help them understand how Lee Raymond received a $400 million severance package from ExxonMobil, which translates into $141,000 a day? What do I say next Saturday to the people who come to my meeting who are struggling to get to work now because they can't afford to put gasoline in their car?

Can you help me get them to understand how it is okay for Mr. Raymond to get a $400 million package and they struggled and oil company profits are at an all-time high?

Mr. SIMON. Well, I would hope that would be behind us by now, Congressman, but I would just——

Mr. CLEAVER. Why?

Mr. SIMON [continuing]. Point out, as we have said before——

Mr. CLEAVER. Why?

Mr. SIMON. Because that is in the past. It hasn't been adhered recently. What——

Mr. CLEAVER. Well, we can only talk about gas prices from yesterday. I mean, everything we talk about here is in the past.

Mr. SIMON. Well, I agree, but yesterday is a lot different than, let's say, when that occurred. But I believe, as we testified before, when you break down that, I think there was a misconception of how much of that was due to past, how much of it was due to future, and how much was due to current earnings there. And I think it was blown out of proportion.

Mr. CLEAVER. So you think I should tell people in my district and probably all over the country that the $400 million package was blown out of proportion?

Mr. SIMON. I think when you look at it, Congressman, and you break it down and you look at that pay package relative to others that were doing the same kind of jobs, you would consider it was competitive. And it was done by outside directors. There was not management involved in that at all. And they looked at others to make sure we are competitive.

Mr. CLEAVER. This is a rhetorical question. Whatever happened to shame?

Since we are having difficulty providing access that I think all of you agreed that we need, are any of you right now going back to oil wells that were tapped out or deemed to be somewhat unprofitable when oil was sold at a far less price? I mean, are any of you now unplugging or upgrading old wells?

Mr. ROBERTSON. Well, we are certainly going back to facilities that maybe oil fields that are producing and looking at the opportunity to put more technology into those oil fields and more ways to extract more from those wells.

So, for example, in the San Joaquim Valley in California, where we have a big field, that field has now been producing for 100 years. It is likely to get up to—originally we probably thought we would be able to recover 320 percent of the oil that is in that field. Today we are looking at ways to get up to 80 percent.

So more technology, higher prices obviously lead to the opportunity to put more money and more technology into existing fields that can make them last a lot longer and make them increase the production. So in that sense, yes.

Mr. CLEAVER. We could get the impression that the oil industry is struggling. I mean, if you listen, you don't think it is struggling.

Mr. HOFMEISTER. I think we struggle for access, Congressman. We struggle for access in which we can have appropriate investments that are making the return on that investment worthwhile.

In other words, we are looking for the ample reserves. We could spend an awful lot more money with very low return if we were looking in the old fields in which a lot of that oil has already been extracted.

I agree with my colleague that there are wonderful technical opportunities to get more from existing fields, but until the nation has a means by which we could use, for example, CO_2 for enhanced oil recovery in the large quantities that would be necessary, many of these old fields will not have the ability to produce a lot more oil.

Mr. CLEAVER. All of your companies are doing well, right?

Mr. ROBERTSON. Well, we are working darned hard. I mean, we have got a big challenge to meet. We have got the world, including this country, that needs a lot of energy. And we are spending and putting more human energy into these investments into these projects than we ever have before. So life is not easy.

Mr. CLEAVER. Well, you are stuck in the 85.13. I think Exxon was 85.45 closed out yesterday. That doesn't sound much like a struggle.

Mr. ROBERTSON. I didn't say it was a struggle. I said we were working hard to try and solve a problem that exists.

Mr. CLEAVER. Thank you, Mr. Chairman.

The CHAIRMAN. The gentleman's time has expired.

The Chair recognizes the gentleman from Oklahoma, Mr. Sullivan.

Mr. SULLIVAN. Thank you, Mr. Chairman. And thanks again for being here.

I believe that global warming is occurring. I think that man has something to do with it. It doesn't have everything to do with it but has a part to play in this. And we want to see a reduction in greenhouse gas emissions as we go forward in the future. And I am trying to kind of boil down what everyone here has said in my mind.

What I think you are basically saying—and I want to see if this is a true statement—is that you believe that we want to spur domestic production, looking at other areas to drill in or explore in, and for gas and oil mainly to displace the oil and gas that we get from other countries.

You said, I think Mr. Hofmeister said or one of you said, that 80 percent of the reserves are owned by foreign companies, national companies. Is that true? Is it something like that?

Mr. ROBERTSON. More than that.

Mr. SULLIVAN. More than that? So, really, you guys collectively represent about, I guess, less than ten percent of the global reserves?

Mr. ROBERTSON. Chevron is 0.6 percent of the global——

Mr. SULLIVAN. I thought it was more than that, actually.

Mr. ROBERTSON. Chevron is 0.6 percent of global oil and gas reserves.

Mr. SIMON. We are 6.

Mr. SULLIVAN. So, really, it is a national security issue. We want to displace that. And you are saying that you are not opposed to moving into renewable fuels, into alternative fuels? You are doing research and development in that. You want to move in that direction and get those accomplished.

But I think, Mr. Hofmeister, again, you said that—and I am for that, too. I want to see us move away from gas and oil eventually in the future, you know, towards renewable fuels. I am for that. But we can't even do it immediately. I mean, in the short term, you said 15 to 20 years to develop this technology. And we need to do that.

I guess my question is I am for all of these renewables. I am for alternative fuels. I think we need to move in that. But basically you are saying that oil and gas are still going to be very much a part of the equation as we move into this new frontier of alternative fuels.

And all of you are willing to do that. All of you think that is what we are trying to do. Would that be a fair statement to say?

Mr. HOFMEISTER. I think it is important for the American people to understand the scale of what is going on in the U.S. economy. Ten thousand gallons of oil a second is consumed in this country, 60 billion cubic feet of gas a day. If we stack those cubic feet on top of each other, it would be from here to the moon and back 25 times. Twenty rail cars of coal are burned a minute in this country. This is every minute of every day and every second of every day.

And so the scale of the massive amounts of hydrocarbons that are consumed to support the world's largest economy and one of the most creative and innovative economies is absolutely necessary. And the demand for electricity continues to rise across this country. We may see a dip in liquid fuel demand because of prices currently and other economic factors, but to be able to move to an alternative requires the technology to make it possible to make it commercial.

What is slowing the movement to alternatives is the lack of commerciality yet. In other words, people aren't making a profit at it. People are investing in it, but they are not yet making a profit.

As we get up larger scale, as we learn more up the maturity curve, I think we will make a lot of money in alternative and renewable energies. And the technology will be a propulsion engine for the nation's economy in the future.

Mr. SIMON. Congressman, I would want to support your comment. When you look at our outlook, if you look at the National Petroleum Council study, if you look at the IEA outlook, oil and gas will continue to represent the dominant source of energy, at least up through the year 2030. If you look at total fossil fuels, including coal, about 80 percent. That is where it is today.

I think when you look at any outlook in terms of the impact of renewables, it is going to be very, very small, down in the two percent, three percent range.

Mr. SULLIVAN. Well, I am from Oklahoma. And I remember when I was in college in the 1980s. I remember a lot of people were petroleum land management. They got out of it.

I know that I have seen people lose jobs. I have seen people get out of this industry. I have seen it hurt my community by people, the down turn by low oil prices. I remember it was $9 a barrel, $16 a barrel. People panicked. The state wasn't getting the revenues that they needed.

So you guys are making record profits right now, but have you ever lost money? You have lost money, too. Would that be a true statement? You have lost money.

Mr. ROBERTSON. Yes. I mean, I was there and head of our North American Division in 1999 when we closed the books and our earnings were zero, zero for North America.

Mr. SULLIVAN. How does your equity investment rate of return compare to other industries, for example? Have you ever done any analysis on that?

Mr. ROBERTSON. Well, as was I think already said, our profits per dollar of sales, which is a typical way of looking across industries, is about 8.3 cents per dollar sales. The average for the U.S. is 7.8.

Mr. SULLIVAN. Another thing, if I could mention, how many people domestically do each one of you employ? And do you offer retirement benefits and then health insurance?

Mr. HOFMEISTER. At Shell, we have about 250,000 people who have jobs because of Shell every day in America. We have about 25,000 working directly for Shell, but in our gas stations, our Jiffy Lube stores, tens of thousands of additional people work.

Mr. ROBERTSON. We have 27,000 Chevron employees in the United States. The average worker, salaried worker, is about $125,000 a year. The average hourly worker is about $75,000 a year. They all have pension plans, and they all have health plans.

Mr. SULLIVAN. Anyone else?

Mr. SIMON. We have about 30. And I would echo what they said in terms of if you look at the pension plan and the amount paid.

Mr. MALONE. Thirty-eight thousand and a multiple of roughly four times contractors in support, a multiple even higher than that, health care pension plans.

Mr. LOWE. Congressman, the point I would make is kind of one of the points you are making. When I started working at Phillips Petroleum Company in 1981, we had over 9,000 employees in

Bartlesville. We went through some rough times. In 1998, we were down to 2,000 employees in Bartlesville. That was due to tough times.

Mr. SULLIVAN. Thank you very much.

The CHAIRMAN. The gentleman's time has expired.

The Chair recognizes the gentleman from California, Mr. McNerney.

Mr. MCNERNEY. Thank you, Mr. Chairman.

With varying degrees of emphasis, each of you has indicated that you have investments in renewable or energy-efficient technology. What I would like to see is what your vision in the long term and the short term is as your companies make up in relation to oil versus alternative new energy technologies, starting with Mr. Robertson.

Mr. ROBERTSON. Well, you know, we are supportive of the data that was in the National Petroleum Council study that basically said in 2030, 85 percent of the world's energy would still come from coal, oil, and gas. So we think we are probably in a fossil fuel environment for some time.

We are spending something like—we are going to spend two and a half billion dollars over the next two years in the area of renewables and energy efficiency. And I think the biggest opportunity—and we have been talking a lot about supply here.

And I know that the biggest opportunity for us, frankly, I think, as a country and maybe as a world is in energy efficiency and using energy more wisely. So I think that, you know, the evidence from our company that goes around doing these projects with public agencies is that we can get 30 percent reduction in use of energy from these projects.

Our own evidence inside our company, we are now 27 percent more energy-efficient than we were 15 years ago. And most of that time we were expecting oil to be $20 a barrel. So there is an opportunity for us all to become a whole lot more energy-efficient.

And, frankly, I still think the number one issue, the number one thing that the—and the Congress did some things in the last energy bill in terms of energy efficiency and appliance standards and those things, but I think in terms of leading the nation, leading the nation, towards becoming a set of energy savers and becoming a—this being a scarce resource, that is the biggest source of energy as far as I am concerned.

Mr. MCNERNEY. Thank you, Mr. Robertson.

Mr. Hofmeister, do you think that we have reached a maximum output possible of oil in historical terms? And if so, do you believe that the Alaska and offshore resources would change that peak oil timing at all?

Mr. HOFMEISTER. I do not subscribe at all to peak oil theory. I think it is a theory that is based upon very narrow assumptions. I think if you look at the National Petroleum Council study, which has been referred to, or other studies around the world, the idea of moving from 80 million, 85 million barrels of production today, which we do, to somewhere near 110–115 million barrels a day is in the focus of most international oil companies and do believe and certainly Shell believes that the world can produce significantly more oil than it does today, even while the focus is on other alternatives.

Mr. McNERNEY. So what is the bottleneck, then? Why are we such a logjam to oil prices?

Mr. HOFMEISTER. I think that is an excellent question. I think there are bottlenecks around the world where, for example, within nations that are oil-exporting nations, where national oil companies dominate, access from international oil companies is limited in many cases.

I think the United States is probably the world's best example of having lots of resources that are not permitted to be developed. And so we are not able to go into 85 percent of the outer continental shelf, for example.

Mr. McNERNEY. So you don't think that the Hubbard's results are accurate or reflect reality?

Mr. HOFMEISTER. Not at all because, in addition to what I have described in terms of what is out there, that theory makes no remarks with respect to unconventional oil, such as oil sands or oil shale.

Mr. McNERNEY. What do you think the makeup of your company will be in terms of oil versus other alternatives?

Mr. HOFMEISTER. Well, we were part and parcel of the National Petroleum Council study, as were other companies. And I subscribe to the outcomes of that study that by 2030, we will still be dominantly a hydrocarbon economy.

Mr. McNERNEY. All right. I am finished with my questions.

The CHAIRMAN. The gentleman's time has expired.

The Chair recognizes the gentlelady from Tennessee, Ms. Blackburn.

Ms. BLACKBURN. Thank you, Mr. Chairman. I am tempted to ask for his extra time, but I won't.

I want to thank you all very much for being here. I am struck by the fact that you have mentioned many times that we have all made choices, our nation has made choices when it comes to energy policy. And those choices have consequences. And I think that some unwise choices 20–30 years ago are yielding what we are seeing today.

And we need to realize that sometimes policy, we need to take a long-term view. And I appreciate that you all are willing to come here and sit down with us and begin to get our hands around this problem and get this thing solved.

I want to just ask you a couple of quick things, but I want to start with this. When a consumer buys a gallon of gas and they are paying their $3.29 at the pump, we know that 69 percent of that is going to crude. And if anybody disagrees with this, I want you to pipe up and tell me. We know that 13 percent of that is going for taxes and that 18 percent is there to cover refining, distribution costs, and marketing. Does anyone disagree with those percentages and allowances? [No response.]

Ms. BLACKBURN. So would it be true that the government actually makes the most as a single entity out of a gallon of gas, that they are realizing the most? Mr. Simon.

Mr. SIMON. That is correct.

Ms. BLACKBURN. That is correct? Okay. Because I think it is so interesting that that is where a lot of the money goes and that is affecting what we are paying at the pump.

I want to come back to a point that was also made about comprehensive strategy because we have to find out how we are going to deal with this. And I am going to borrow from you, Mr. Hofmeister. I think you are exactly right: short-term, mid-range, and long-term.

What I would like to hear from you is what you all are doing in each of those categories. And I am not going to ask for you to sit here and articulate anything right now because we know some of the things that you are doing for alternatives and for future. I would like to have this in the form of just one sheet when we are talking with individuals.

You didn't cause all of this problem. Policy has caused part of this problem. You all may be partly to blame. The House and the Senate and the administration can all be partly to blame in this. The problem is we weren't looking far enough down the road early enough to address it. And, as I said, that should have been a few years back.

We do need to work on something that is a comprehensive strategy for this country that is going to consider supply, demand, that takes into account a global marketplace, takes into account that you all are dealing with companies that are owned by governments, that are not independently owned.

So I am going to ask you all to submit that to us, what you are doing that you think will give us the greatest impact in the short term, where your mid-range focus is as we look toward 2030 and we look toward our fossil fuel needs moving toward 2030, what you are doing there, the policies that would help us with that and then long term the policies and the actions that we can take that create the environment for you to do your best. I would like to hear that.

And then my last question that I wanted to touch on, windfall profits tax, like the ones that were proposed last year, how would that affect your bottom line? And what would it do to fuel prices? Mr. Malone, I will start with you. And let's just work down the line.

Mr. MALONE. Well, we are investing dollar for dollar in this country. So you take a dollar more in taxes. It is going to be a dollar left available for investment.

Ms. BLACKBURN. Very good.

Mr. Lowe.

Mr. LOWE. Yes, same for us.

Ms. BLACKBURN. Same?

Mr. LOWE. It just reduces the amount of supply.

Ms. BLACKBURN. Okay.

Mr. ROBERTSON. I think what this Committee is after is increasing supply of energy, not reducing. I think that would reduce it.

Ms. BLACKBURN. Okay.

Mr. HOFMEISTER. I think windfall profits were tried before. And it has resulted in some of what the problem is we face today: lack of supply. And I would also say we are dollar for dollar in the United States.

Ms. BLACKBURN. Mr. Simon.

Mr. SIMON. I would say the same. The policy if you tax something, you are going to get less of it.

Ms. BLACKBURN. Okay. And, Mr. Simon, I want to clarify one thing. In your testimony, you said from '03 to '07, your earnings grew by 89 percent, but your income taxes grew by 170 percent. Over the last 5 years, ExxonMobil's U.S. total tax bill exceeded your U.S. earnings by $19 billion.

Mr. SIMON. That is correct.

Ms. BLACKBURN. That is correct?

Mr. SIMON. That is correct.

Ms. BLACKBURN. Okay. Thank you, sir.

Mr. Chairman, thank you. I yield back.

The CHAIRMAN. Great. The gentlelady's time has expired.

The Chair recognizes the gentlelady from California, Ms. Solis.

Ms. SOLIS. Thank you.

I have been listening attentively to many of your statements regarding different investments that you all have made. And I want to particularly commend BP, Mr. Malone, because I had an opportunity on a visit with this Select Committee. We visited the Chancellor Merkel and some folks, some business folks, out there and had a very extensive discussion with your representative about solar panels and investments here in the United States and collaboratives that you have with universities. And it seems to me that you made an investment a long time ago, maybe a decade ago, that you were going to address this issue of green gases and how CO_2 is affecting our entire environment.

I failed to understand why your other colleagues haven't been able to maybe come up to speed in that same vein. And I wonder what led you, then, to make those kinds of decisions, to make those investments because you are a global market.

Obviously your tentacles are everywhere but especially in the EU. And because there are dramatic changes occurring there with governments, I think that has, in my opinion, given you the impetus to do more.

So if you could just touch on that? Because what I am trying to sense here is that we are not doing enough to create an incentive so that your other colleagues would do the same. But I see that happening in Europe. Tell me what you see.

Mr. MALONE. Well, just a couple of comments. Yes, early on, my company—although the science was incomplete, we made the policy decision that we could not take the risk with global warming while we are waiting for science to settle. And that was our decision seven years ago. What we have been asked——

Ms. SOLIS. Would you put a price on that risk at that time? Was there a risk factor there——

Mr. MALONE. No.

Ms. SOLIS [continuing]. For you to fail?

Mr. MALONE. No.

Ms. SOLIS. No?

Mr. MALONE. No.

Ms. SOLIS. Okay.

Mr. MALONE. No. But we knew that we were in the carbon business. And we knew that our business emits greenhouse gases and that we needed to start. And we implemented—a number of things have been referenced here internally.

I think the important thing, though, there is a missing link now. We are seven years down the road. And we still don't have any way to price and market carbon in this country. So, even though you can do some things internally, we are now faced with these refineries we are talking about with greenhouse gas emission increases of CO_2. And if you can't sequester it, there is no market mechanism for us to be able to move forward.

So seven years later, we do have the ability to have acted on a piece of legislation. And we are hoping to be a part of that.

Ms. SOLIS. Okay. One of my other concerns is that most of you here talked about the barriers that federal government or maybe even local government has put up roadblocks for you to develop those current leases that you have. Could you tell me specifically why you have not been able to develop those leases that you currently have that have about 80 percent of the oil, the U.S. oil, that is available? And I will go to Mr. Simon.

Mr. SIMON. I don't know of any that we are not developing. Those that we already have access to, developing in as rapid a fashion as we can.

Ms. SOLIS. Go on to the next.

Mr. HOFMEISTER. Leases are generally a ten-year time horizon. And during that period of time, we are continuously evaluating where we can best use our technology and science to develop those leases.

Sometimes ten years isn't long enough because of the tremendous capital expenditure that is necessary. For example, in the Gulf of Mexico, it is easily a billion dollars now for a major deep water project in just one lease.

Ms. SOLIS. But then how do you explain your record profits that are well over one billion——

Mr. HOFMEISTER. Well, the profits——

Ms. SOLIS [continuing]. That can't be redirected in some way or apportioned?

Mr. HOFMEISTER. The profits are cumulative around the world, but in the case of, let's say, the Gulf of Mexico, we are limited by the amount of manpower that we have. We don't have the kind of human resource that can do all of the leases simultaneously. And so we do——

Ms. SOLIS. So the obstacle isn't from the federal government. It is a market obstacle. That is your obstacle.

Mr. HOFMEISTER. The federal government's obstacle has been to prohibit the granting of leases in the outer continental shelf more broadly. Had we had the confidence that we could do more leasing, we would be scaling up our operations to go after more leases.

Mr. ROBERTSON. I am not sure whether there is a misunderstanding here, but certainly all the leases that we have—that we have spent money on with the government—we are working on and trying to develop.

And obviously we work the biggest prospects. I mean, once you get a lease, then you do some work on it. You do some seismic work. You do some drilling. And you see which ones are the best to develop. And we develop them. After a period of time——

Ms. SOLIS. But there are different stages of that development.

Mr. ROBERTSON. Yes, but after a period of time——

Ms. SOLIS. And not all of them are——

Mr. ROBERTSON. After a period of time——

Ms. SOLIS. The spigot isn't open on all of them is what I am trying to get at.

Mr. ROBERTSON. After a period of time if we don't do something, we have to turn it back to the government. So we are working on the leases.

You asked another question about so many years ago. Twenty years ago Chevron started developing geothermal energy in California. Today Chevron is the largest geothermal energy company in the world. It is still relatively small in the scale of the world's energy business, but it is 1,200 megawatts of power.

So I think we have been doing this for many, many years.

Ms. SOLIS. Mr. Chairman, could I just ask——

Mr. ROBERTSON. It makes a difference.

Ms. SOLIS [continuing]. If we could get from the witnesses a listing of those current leases and at what stage they are at so I have a better understanding of what is in existence, what is being utilized, and what isn't?

The CHAIRMAN. Okay. The gentlelady has propounded that request. Would the witnesses at the table be willing to——

Mr. LOWE. A short example, when lease acreage has become available; for example, two Gulf of Mexico deep water lease rounds last fall, a recent Chukchi Sea lease round off Alaska—ConocoPhillips has been high bidder on a billion dollars for those leases. So we are starved for access. Access really is the issue.

The CHAIRMAN. We would ask for that information to be provided for the record to the Committee.

The gentlelady's time has expired.

The gentleman from Oklahoma. For what purpose does the gentleman seek recognition?

Mr. SULLIVAN. Mr. Chairman, I would like to ask unanimous consent to enter the National Petroleum Council's book, "The Hard Truths About Energy." If I could submit this?

The CHAIRMAN. Without objection, it will be included in the record.

[The book offered by Mr. Sullivan follows:]

Mr. SULLIVAN. Thank you, sir.

The CHAIRMAN. Thank the gentleman.

The Chair recognizes the gentlelady from South Dakota, Ms. Herseth Sandlin.

Ms. HERSETH SANDLIN. Thank you, Mr. Chairman.

On March 24th, Patrick Barta wrote in the Wall Street Journal that "Without biofuels, oil prices would be even higher" than they are now. His report cited Francisco Blanch at Merrill Lynch as observing that, according to the piece, "oil and gasoline prices would be about 15 percent higher if biofuel producers weren't increasing their output," meaning oil would be priced above $115 per barrel.

Do each of you agree with Blanch's analysis, "Yes" or "No"? And if not, why not?

Mr. LOWE. I think there is an argument there. Roughly five percent of liquid fuels are now ethanol in this country, some small amounts of biodiesel. I think there would be some impact, but I don't know that it would be 15 percent.

Mr. ROBERTSON. I think any amount of additional energy in the world will directly lower prices. So more oil would lower prices. More gas would lower prices, more coal, more biofuels. So I have no doubt that it has some marginal effect. I would be very surprised if it is as big as you suggest.

Mr. LOWE. Certainly directionally I would agree. That is why we need all forms of energy.

Mr. MALONE. I would agree.

Mr. SIMON. I would just point out I think you have got to look at the cost associated with producing biofuels versus gasoline out of crude. If you look at $5 per bushel of corn price today and $100 per barrel crude, the production cost of biofuels is about $3.15 a gallon. And crude is $2.70. So it is hard for me to see how that would have a positive impact in terms of the price of gasoline that people pay in terms of the biofuels there.

Ms. HERSETH SANDLIN. So you don't agree, Mr. Simon, that it has any impact whatsoever in light of what you claim to be the production cost of corn ethanol today?

Mr. SIMON. I think we have got to be careful if you think you are lowering the price that the consumer pays at the pump by mandating a higher cost liquid fuel that goes into producing——

Ms. HERSETH SANDLIN. Right. I understand you probably have been opposed to the renewable fuels standard either, the one that we included in the 2005 Act or even the one that we recently passed. Is that correct, Mr. Simon?

Mr. SIMON. Our corporation does not think that mandates and subsidies are the right approach.

Ms. HERSETH SANDLIN. What is the percentage of ethanol that ExxonMobil blends in U.S. gasoline today?

Mr. SIMON. Today we blend about eight percent.

Ms. HERSETH SANDLIN. Eight percent. And so you would be blending that, even if there wasn't a renewable fuels standard?

Mr. SIMON. No, that is not correct. I think if there were not a renewable fuel standard, it would be lower than that.

Ms. HERSETH SANDLIN. And do any of your companies support higher ethanol blends beyond E10 in light of recent studies that suggest a blend of 20 percent and even 30 percent ethanol increased fuel efficiency and do not pose any types of damage, corrosive damage, to the vehicles, as some have suggested?

Mr. ROBERTSON. Well, to start with, we are working in California to get the limit raised from 5.7 percent, which is today's limit in California because of environmental restrictions, to 10 percent. So that is the first place we have got to go.

I do believe that going over ten percent in the nation would stretch the food system to the point that you don't want to go any further. So we have the first generation, second generation ethanol from cellulosic conversion. And we are working as hard as we know how to generate that kind of technology and to produce that kind of stuff.

So going beyond ten percent across the country would not work in today's environment.

Ms. HERSETH SANDLIN. You mentioned the impact on food prices. And I think that there was perhaps some suggestion of this, Mr. Simon, in a comment you made in your opening statement about developing renewable fuels and leading to unintended consequences.

Mr. SIMON. Yes.

Ms. HERSETH SANDLIN. Do any of you have any independent analysis that you can share with the Committee that it has been the cost of the price per bushel of corn or wheat that has directly led to the increase in food prices and what percentage that constitutes versus energy costs associated with processing or transporting the food?

Mr. ROBERTSON. I do not that I am aware of.

Ms. HERSETH SANDLIN. None of you have any independent analysis to make that claim?

Mr. SIMON. I think there have been independent studies done in that regard, but we certainly don't have them.

Ms. HERSETH SANDLIN. Okay. But you tend to cite——

Mr. SIMON. I believe based on all that I have read from lots of different places that the price of food has been impacted by the requirement to turn a lot of corn into ethanol.

Ms. HERSETH SANDLIN. And would you also agree with the statement, though, that the price of food is also affected by increased energy costs?

Mr. SIMON. Sure.

Ms. HERSETH SANDLIN. But you haven't done any independent analysis that would break down the percentages associated with energy versus other commodities?

Mr. SIMON. I have not.

Ms. HERSETH SANDLIN. Okay. Well, my time is up. So I will yield the remainder of my time. Thank you, Mr. Chairman.

The CHAIRMAN. Okay.

Ms. HERSETH SANDLIN. Oh, one last question. Are any of the other four companies, other than ConnocoPhillips, test marketing E85 or biodiesel?

Mr. HOFMEISTER. Yes. Shell has a test market in Chicago where we are looking at consumer acceptance of the product.

Mr. ROBERTSON. We have got a test going with the State of California with several hundred vehicles that are running on E85. And we sell E85 at a very small number of service stations around the country.

Mr. SIMON. We have E85 at only about 30 service stations.

Mr. MALONE. We have limited E85. We are waiting on some pump approvals. But we do have it under the canopy now.

The CHAIRMAN. The gentlelady's time has expired.

The Chair recognizes the gentleman from New York State, Mr. Hall.

Mr. HALL. Thank you, Mr. Chairman. And forgive me if my questions were already asked by somebody. I was across the street at another hearing.

I wanted, first of all, to comment on my colleague and my friend from Tennessee, who is no longer here, Ms. Blackburn's statement that the actions of Congress so far on energy have not gotten results. And I would just point out that, as I understand it, the attempt by the House to take back the $14 billion the previous Congress had given in tax breaks to oil companies has not passed the other body or been signed by the President. So that has no effect on what is going on.

And, secondly, the energy bill we passed with the CAFE standards increased was signed in December, just a couple of months ago. And, therefore, we are looking at 2020 before that goal is supposed to be reached. So one couldn't reasonably expect that that action would already be doing much visibly.

Here is a question. I have got a constituent who called one of our offices in Carmel, New York and said, "I just bought myself a flex fuel vehicle. Where can I get some flex fuel?" And our staff had to disappoint her by telling her that, to our knowledge, there were only two pumps in New York at the time selling E85.

And the question is, to the extent that you have stations? I understand many gas stations are independently operated, but many others are run under the flag of your companies.

Could you or would you have a policy or make a commitment to have at least one biofuel pump at each gas station? And if not, why not? Forgive me if you have already answered that question but maybe Mr. Simon and then down the row.

Mr. HALL. No, I would not make that commitment. We don't make a biofuel. Therefore, we cannot warranty it. And, therefore, we would not want to sell it under our brand. We do not deny our dealers the right to do so, but they simply cannot do that under our brand.

Mr. HALL. Okay. Thank you very much.

Mr. Hofmeister.

Mr. HOFMEISTER. I mentioned a few minutes ago that we do have a pilot project at company-owned stations in Chicago in which we are testing the market acceptance of E85. I must say that the results are very poor to date from a consumer acceptance standpoint.

But we do not prohibit our independent dealers and franchisees across the nation from making a decision to put a pump on their site.

Mr. HALL. Thank you very much. I am sorry for cutting you off. I just have a short time here.

Mr. ROBERTSON. Yes. I mean, the——

Mr. HALL. Same?

Mr. ROBERTSON. The vast majority of service stations in the United States flying a Chevron flag are independently owned.

Mr. HALL. Right.

Mr. ROBERTSON. They are entitled to put in——

Mr. HALL. If they want, they can do it?

Mr. ROBERTSON [continuing]. A fuel pump if they want. They have to make sure that it doesn't interfere with the brand, but they can do that. And some have.

Mr. HALL. Okay.

Mr. LOWE. Yes.

Mr. HALL. Mr. Lowe.

Mr. LOWE. ConnocoPhillips is test marketing E85. Potentially we have identified over 2,500 sites. But, as Mr. Hofmeister noted, so far the consumer acceptance hasn't been very——

Mr. HALL. And, Mr. Malone.

Mr. MALONE. We do have sites that are non-BP-owned that have E85. We don't prohibit it. We are very concerned, though, about the UL listing on the pump.

Mr. HALL. Right. Okay. Diesel obviously is a different kettle of fish. I mean, I am burning similar fuel, burning 20 percent biodiesel in my home heating oil. And it doesn't seem to require an adjustment to the system. I have friends who have driven off-the-lot diesel vehicles made in America that were driven actually on 100 percent biodiesel from wood in this particular instance.

I wanted to ask if you—I am sure you are all familiar with the Fischer-Tropsch reaction and the use by the Nazis during World War II to make liquid fuels from coal. There have been some studies recently showing that this can be done taking carbon dioxide from the air and especially in parts of the country where there is nearly constant sunshine or nearly constant wind to use renewables as the driver for this process.

Are you aware of this or is this among the things that any of you are studying? Mr. Hofmeister, maybe you would go first on that.

Mr. HOFMEISTER. Our work thus far has been on solid materials, not gaseous materials other than natural gas, which we are turning into a liquid form for fuel purposes.

Mr. ROBERTSON. Well, we have a global joint venture with Sasol of South Africa, who have been the main users of Fischer-Tropsch technology. And we are building a gas-to-liquids plant using Fischer-Tropsch technology. But I am not aware of a system that can take carbon dioxide out of the air if that is what you were saying.

Mr. HALL. It might be worth looking into. And it would be a huge public relations boon not to mention, I think, a moneymaker for you.

And the last question I guess I would ask you because it is amazing how fast five minutes run out, I wanted to ask you if I could be imprecise here, if you are making, say, $2 gazillion of profit in a given time period, would you consider using half a gazillion or a quarter of a gazillion or whatever, however much of your advertising budget.

Now that a number of you have said conservation is important, demand management is important, would you as a patriotic move and for the good of I think all of us in the United States, certainly our national security, use some piece of your advertising budget to tell people that they should conserve, that it is patriotic to conserve and that it is certainly good for——

Mr. HOFMEISTER. Shell does that in all of its 14,000 branded stations across the country currently.

Mr. ROBERTSON. I think if you have been looking at Chevron advertising, you see a lot of our conservation but absolutely.

Mr. LOWE. Yes, we are already doing it.

Mr. MALONE. We are already doing it.

Mr. SIMON. We are a strong proponent of using our products more efficiently and work hard to educate the public in that regard.

Mr. HALL. I will be looking for that advertising more. Thank you.

Thank you, Mr. Chairman.

The CHAIRMAN. Okay. The gentleman's time has expired. And all time for questions by the members of the Select Committee has expired. But Mr. Stupak has been waiting for 2 hours and 40 minutes to ask questions. And Ms. Jackson-Lee has been a more recent arrival. But out of courtesy to them, I make a unanimous consent request that they be allowed as guests of the Select Committee to ask questions of the witnesses who are testifying before us today.

Mr. SENSENBRENNER. Mr. Chairman, reserving the right to object, I am not sure that a committee can by unanimous consent suspend a House rule that applies to the Committee. And I am looking specifically at House rule 11(2)(g)(ii)(c), which says that other members are welcome at committees but in a non-participatory manner.

And I would ask the Chair to withdraw the unanimous consent request because I don't think that it is proper and in compliance with the rules to waive a House rule in a committee.

The CHAIRMAN. Well, if the gentleman would yield——

Mr. SENSENBRENNER. I yield.

The CHAIRMAN [continuing]. Under House custom, any one of its rules can be waived by unanimous consent. And, again, I remake that proposal to the members of the Committee——

Mr. SENSENBRENNER. Well——

The CHAIRMAN [continuing]. That we waive the rule by unanimous consent.

Mr. SENSENBRENNER. Well, reclaiming my time, I don't think that we can waive a House rule in committee. I think that that requires an action by the House, largely through the Rules Committee. So I object.

The CHAIRMAN. The Chair hears an objection. And, as a result, the Chair is constrained by that objection to recognize the guests of the Committee.

Mr. STUPAK. Jim, if you were going to object, why didn't you tell us three hours ago?

Mr. SENSENBRENNER. Well, I move to strike the last word. I did not know that there would be this request that would be made. It was not cleared with the minority.

The CHAIRMAN. I apologize to the gentleman from Michigan. I appreciate the——

Mr. STUPAK. No apologies necessary. What goes around comes around.

The CHAIRMAN [continuing]. Position that the gentleman has been——

Ms. JACKSON LEE. I thank you for extending the offer, Mr. Chairman. It is an important issue. And we are here for that reason. I was here starting from 1:00 p.m. Thank you.

The CHAIRMAN. Thank the gentlelady.

So we have reached the conclusion of this hearing. I would say to the oil company executives that, as President Kennedy used to say, to those whom much is given much is expected. There has been a windfall of revenues, which has fallen to the oil companies represented here over the last several years. It is highly likely to continue this year and into the indefinite future.

I think that with that great opportunity that you have been given, there is a responsibility that you have to discharge. As I asked earlier, there should be a commitment that each of you make. I would recommend that it be ten percent of your profits go into renewable energy projects.

We will not be able to solve this global climate challenge unless you do so. You are the leading energy companies in our country and in the world. We cannot solve this problem without your full participation.

And, similarly, consumers will not be able to deal with this issue without your focused attention upon them. The poorest, the working class are going to be devastated. They will have to choose between heating and eating. We are reaching that point in our country. And it is your responsibility to deal with this issue in a responsible fashion.

To the extent to which you don't have to take all of this as profit and you can lower your prices, I think you should do so. To the extent to which you can deal with this as an issue of speculation in the marketplace and you can support the deployment of the strategic petroleum reserve, which I recommend as a way of piercing this speculative bubble, I recommend that you take that position.

I recommend that you take any position that helps the consumer and that will help this renewable energy revolution. But that is up to you. But all I can tell you is—and I can predict this with a guarantee—that this is the first of many hearings that you are going to have this year before the Congress.

My father always said try to start out where you are going to be forced to wind up anyway. And so I am asking you each to deal with that issue of the amount of your profits that you put into renewable energy resources this years and for every subsequent year and to also deal with this issue of how it is going to affect blue collar and poor citizens of our country.

We thank you each for your testimony here before us today. And, with that, this hearing is adjourned.

[Whereupon, at 2:46 p.m., the foregoing matter was concluded.]

EXXONMOBIL RESPONSES TO POST-HEARING QUESTIONS: SELECT COMMITTEE ON ENERGY INDEPENDENCE AND GLOBAL WARMING U. S. HOUSE OF REPRESENTATIVES (APRIL 1, 2008 HEARING)

(1) How much did your company invest in renewable energy technologies by year and by project over the last 10 years?

A: ExxonMobil shares the same goal as policymakers — to meet the world's growing energy demand while lowering the projected growth in greenhouse gas (GHG) emissions. We approach this by:

a) improving energy efficiency and reducing GHG emissions in our own operations;
b) improving the efficiency of consumers' use of energy; and
c) conducting or sponsoring research that could lead to breakthroughs in alternative energy.

We are taking significant actions to assist:

a. Improving energy efficiency and reducing emissions in our own operations

Since 2004 we have invested more than $1.5 billion in activities that reduce GHG emissions and improve energy efficiency, and we will be spending at least $500 million on additional initiatives over the next few years.

We are an industry leader in the use of cogeneration applications, which capture waste heat for use directly within our manufacturing and production facilities. We have interests in about 100 cogeneration facilities in more than 30 locations worldwide, which have the capacity to reduce global CO_2 emissions by more than 10.5 million metric tons per year. The combined power generation capacity at facilities in which we have an interest was more than 4.5 gigawatts in 2007. With new facilities under construction around the world, we expect to increase this capacity to more than 5 gigawatts in the next three years.

Additionally, across our operations, we are working to reduce flaring of natural gas. For example, in Nigeria we and our co-venturer are investing more than $4 billion in gas utilization and commercialization projects to help eliminate routine gas flaring.

ExxonMobil launched its proprietary Global Energy Management System (GEMS) in 2000, through which we have identified opportunities to improve energy efficiency at our refineries and chemical plants by 15 to 20 percent. We have implemented about 60 percent of these opportunities. Our refining and chemical operations achieved best-ever energy efficiency in 2007. Over the past several years, we have been improving the energy efficiency of our refining and chemical businesses at a rate two to three times faster than the industry.

Through efficiency actions taken in 2006 and 2007, we reduced GHG emissions by about 5 million metric tons in 2007, equivalent to removing about one million cars from roads in the United States. We are also on track to meet our target of improving energy efficiency across our worldwide refining and chemical operations by at least 10 percent between 2002 and 2012.

b. ***improving the efficiency of consumers' use of energy***

We are actively involved in improving energy efficiency of consumers' use of our products, promoting low-emissions technologies that are deployable today, such as tire liners that keep tires inflated longer; advanced fuel economy engine oil; and light weight automobile plastics. Utilization of technologies such as these in one-third of U.S. vehicles would translate to a savings of about 5 billion gallons of gasoline annually and yield GHG emissions savings equal to taking about 8 million cars off the road.

In addition, we are working on other technologies both for the mid- and longer-term that address the need for both improved fuel economy and reduced emissions. These include separator films for lithium ion batteries that could accelerate the adoption of hybrid vehicles, and our collaborative research with auto and engine makers on technologies that may enhance fuel economy by up to 30 percent. ExxonMobil is also conducting research into hydrogen generation on board vehicles to power fuel cells which could improve fuel economy by 80 percent and reduce emissions by as much as 45 percent. Recently, we also announced a more than $100 million investment in a new technology for separating CO_2 from natural gas, which could help commercialize some applications of carbon capture and storage (CCS). We are currently building a demonstration plant for this technology in Wyoming.

c. ***conducting or sponsoring research that could lead to breakthroughs in alternative energy***

A primary value we also bring is through financial and technical support of breakthrough research to overcome the economic and technological barriers inhibiting these sources from being applied on a broader scale. On the research side, we are spending more than $100 million in 2008 on alternative energy and efficiency improvement technologies, and technology for separating CO_2 from natural gas, which could have a significant longer term impact on reducing emissions. We agree with the view that in order to meet future energy demand, we are going to need a wide range of energy sources — including wind, solar, nuclear, coal, biofuels, oil and natural gas.

Five years ago, ExxonMobil initiated the Global Climate and Energy Project (GCEP) at Stanford University to identify future step-out advanced energy technologies. ExxonMobil has committed $100 million to this project over ten years. GCEP now funds research programs in the United States, Europe, Australia and Japan.

Our investment in groundbreaking research at GCEP represents our commitment to work to meet future energy needs with significantly lower GHG emissions. GCEP is the largest privately funded low-greenhouse-gas-energy research effort in history. This project aims to undertake fundamental and pre-commercial research on a wide range of technologies that offer the potential to supply and use energy with significantly reduced GHG emissions. Emphasis is on breakthrough research that can enable widespread, commercial solutions in a broad portfolio of areas including:

- How hydrogen and solar energy can be made economically;
- How engine and fuel systems can be made significantly more efficient;
- How carbon dioxide capture and storage can be made more effective; and
- How biofuels can be made with greater yield and lower emissions.

(2) How much does your company plan on investing in renewable energy technologies by year in coming years?

A: ExxonMobil plans to invest more than $100M in research and development on energy efficiency and alternative energy in 2008. Due to the competitive nature of R&D investments, ExxonMobil is not in a position to share future planned spending in this area in the coming years.

ExxonMobil remains focused on meeting the growing energy demand projections in the next few decades and the realities of various investment options to meet those demands. Increased energy supplies will serve as the foundation of a growing global economy and the tremendous expansion of living standards throughout the developing world. We therefore assess pragmatically the role that alternative energy sources can play in meeting these future needs. Even as wind and solar energy are likely to grow at about 10 percent per year on average, supported by government subsidies and mandates, they will account for about 1 percent of global energy demand in 2030. Costs and intermittency remain challenges to expanding use.

The advantages of oil and natural gas across a broad array of applications provide economic value unmatched by any currently available alternative. On any assessment, oil and gas will continue to play a significant role in meeting energy demand for many years to come. And that is where ExxonMobil's strengths lie — to use our technology, the expertise of our people and our global scale to safely and reliably supply the oil and gas that is, and will continue to be, needed to power the American economy, and to improve the environmental performance of our products and operations.

(3) Based on the fundamentals of supply and demand, what does your company estimate the price of oil should be were it not for speculation, and other factors? Mr. Simon from ExxonMobil testified that their analysis of fundamental supply and demand suggests a price of oil in the $50-55 range, and prices above that figure are due to speculation, weakening dollar and geopolitical stability. Do you agree or disagree with that analysis?

A: We are unable to quantify the effect on crude oil price that may be attributable solely to speculation.

Crude oil prices are influenced by a multitude of factors. These include physical and fundamental factors, such as supply, demand, inventory, and spare capacity, as well as expectations of the market participants on such matters as potential weather-related effects and outlooks on the growth of supply, demand, and capacity. In addition, crude oil prices can be affected by currency exchange rates, geopolitical risks, and actions of investors and financial institutions. It is not possible to identify definitively the impact of individual factors on crude prices because many of the factors may be correlated to each other. Thus, it is not possible to identify a price per barrel for any given moment that can be justified purely by the supply and demand in the market.

(4) What percentage of the current price of oil is a result of speculation?

A: See response immediately above.

(5) How much did your company invest last year in emerging energy technologies in North America and what types of technologies would that include?

A: ExxonMobil invested more than $50M in R&D on emerging energy technologies in 2007. Emerging energy technologies are defined here as technologies for production of non-oil transportation fuels, generation of hydrogen on a vehicle, solar, wind, geothermal, biofuels, as well as technology components such as advanced batteries and CCS.

Additionally, ExxonMobil spends more than $1 billion annually on energy technology development. Our technology spend is focused on increasing supply, lowering cost, lowering environmental footprint, and supplying improved products in our oil and gas, refined products, and chemicals business.

(6) In 2030, what percentage of global energy demand will be met by fossil fuels?

A: Fossil fuels will remain indispensable to meeting total projected energy demand growth Even with assumptions for dramatic growth in solar, wind, and biofuels, fossil energy is generally forecast to continue to supply roughly 80 percent of the world's energy needs through 2030, according to the U.S. Energy Information Administration (EIA) and the International Energy Agency. Approximately 55-60 percent of supplies will be provided by oil and natural gas.

(7) Do you think that it is important as an energy security issue, to use more of the U.S. reserves of oil and natural gas? What are the best policies to assure our energy independence?

A: An estimated 37 billion barrels of conventional recoverable oil and 171 trillion cubic feet of natural gas – enough to fuel nearly 12 million cars and heat 25 million homes for a hundred years – is believed to be on lands currently ruled off-limits for production by the federal government. A significant majority of Americans believe Congress should join the President in lifting existing limitations and opening more acreage to responsible production. If Congress were to do so, it would make new energy supplies available to Americans in the future, send a positive signal to markets, put downward pressure on prices, and strengthen U.S. energy security by further diversifying Americans' energy portfolio; therefore, reducing the impact of a disruption in any one producing region of the world.

"Energy independence" is generally not realistic or achievable for most nations. Most of the world's major economies import oil and natural gas to meet their energy needs, including our own. Eight of the world's ten largest economies are net importers of oil, including the U.S. Greater efficiency and the increased use of alternatives can increase global energy supplies, but no combination of the two can realistically close the gap between energy demand and domestic supplies in most nations.

Energy security is an important policy objective, which does not necessarily entail "energy independence." Allowing more access to all sources of conventional energy supplies, and most particularly domestic resources can both increase independence, but more importantly, increase our overall energy security. Smoothly-functioning global markets are essential to energy security. Free and open global markets enable the broad access to and application of new technologies to increase production and improve efficiency, and they facilitate matching energy supplies with demand.

(8) What percentage of your stock is own by pension plans and retirement accounts?

A: ExxonMobil is a large, publicly traded integrated oil company. Our shares are held by both retail and institutional shareholders. Retail or individual investors, hold approximately 40 percent of our outstanding shares. The remaining approximately 60 percent is held by institutional investors, who manage mutual funds, pension plans and retirement accounts. The specific share of pension funds and retirements accounts alone is not available from public filings. Through direct or indirect shareholdings, many, many Americans invest in ExxonMobil.

(9) Do you support the use of coal-to-liquids as an alternative to traditional petroleum? If not, why not? As a follow up, wouldn't the use of coal-to-liquids significantly increase our domestic supply of fuel?

A: ExxonMobil has many commercial technologies today, and continues to invest in R&D for processes that could be used to convert coal to fuels, lubricants, and chemicals. In the area of fuels and lubricants, the processes include gasification of coal to synthesis gas, conversion of synthesis gas to fuels and lubricants, and CCS processes.

From 2003-2007, ExxonMobil invested more than $150M in R&D that could be used to advance economic conversion of coal to transportation fuels and lubricants.

While these technologies exist in varying forms of maturity, today they do not deliver fuels required by consumers at a competitive cost to conventional transportation fuels, nor do they result in overall lower GHG emissions.

(10) How much bio-fuel and ethanol do you think realistically can be substituted for traditional petroleum?

A: In the mid-term, e.g., ~2012, biofuels face several practical limitations. Based on EIA projections for 2012, these limitations translate to approximately 14 billion gallons of ethanol and approximately 1 billion gallons of biodiesel in the U.S. fuel supply.

(11) Are you involved in developing production in Canada's oil sands or Western oil shale? Do you believe those alternatives will become more viable if the price of oil continues to rise?

A: The economic viability of projects is dependent on long-term price; but that is only one of a number of factors that influences long-term investment decisions. Investment decisions are based on an evaluation of all circumstances surrounding an opportunity, including available technology; the estimated resource size; exploration and development costs; environmental concerns; and the fiscal regime, political and economic risk of the country in which the resource is located.

Oil Sands:

Canada's oil sands deposits are estimated to contain as much as 173 billion barrels of economically viable oil. The oil sands now represent half of western Canada's oil output.

The United States is already the largest market for Canadian oil by far, with well over 1.8 million barrels per day exported to the U.S. in 2007, (or 18 percent of U.S. crude oil imports). About half of these imports come from oil sands, where production in 2006 was over 1.1 mbd and forecast to reach roughly 3.4 mbd in 2015, according to the Canadian Association of Petroleum Producers (CAPP).

ExxonMobil is actively involved in developing Canada's oil sands resources through our majority shareholder position in Imperial Oil Limited (IOL). IOL's oil-sands assets are located primarily at three sites.

- Cold Lake is IOL's largest single asset and is the largest in-situ oil-sands operation in Canada. Current production of more than 150 Kbd of bitumen represents about 40 percent of Canada's thermal in-situ oil-sands production. It also represents about five percent of Canada's total oil production.
- Holding a 25 percent interest, IOL is the second-largest owner of Syncrude Canada, the largest oil-sands mine in the world. Current production from Syncrude is more than 350 Kbd, one in every 8 barrels of oil produced in Canada.
- The Kearl Oil Sands Project would develop a new oil-sands mine in the Fort McMurray region. This is a 100 percent Imperial and ExxonMobil project, and has the potential to produce more than 300 Kbd for over 40 years.

In addition to these three opportunities, IOL holds an extensive undeveloped oil-sands acreage position, and some very promising development opportunities, in both mining and in situ areas.

ExxonMobil is also in partnership with IOL on integrated research efforts to enhance the effectiveness of our existing technologies and develop new, breakthrough technologies that have the potential to realize significant improvements and to commercialize resources that are currently not attractive.

Oil Shale:

According to the U.S. Bureau of Land Management (BLM), oil shale resources on federal lands contain an estimated 1.23 trillion barrels of oil - more than 50 times the nation's proven conventional oil reserves.

ExxonMobil fully supports government efforts to advance oil shale development and believes it is important to continue to encourage a broad range of technologies and many different companies to find the best commercial solutions. However, experience tells us the responsible path is to take a careful, phased approach to evaluate the various technologies thoroughly before making premature forward-looking statements on potential commercial production.

Of all the in situ technologies currently under study, none has yet demonstrated commercial viability. ExxonMobil's leading technology candidate is the Electrofrac™ process. This method heats oil shale in situ by hydraulically fracturing the rock and filling the fracture with an electrically conductive material, forming a circuit through which electric current can flow, thus creating a heating element. The hydrocarbons from the heated shale can then be brought up to the surface with vertical wells much like conventional oil and gas.

ExxonMobil was not awarded one of the five initial research leases on federal lands, which means we have limited opportunities to test our technology. We remain interested in securing leases best suited to in situ oil shale research and development.

(12) The American Jobs Creation Act provides a tax credit of up to $1.00 per gallon for the sale and use of "agri-biodiesel" -- biodiesel from virgin agricultural products. The credit is $0.50 per gallon for biodiesel from recycled grease. In addition, the law provides an excise tax credit for biodiesel blends (i.e., biodiesel and conventional diesel). Producers are eligible for one credit or the other, but not both. The Energy Policy Act of 2005 extends these credits through 2008. Do you support making these credits permanent? Do you support increasing these credits?

A: ExxonMobil believes that we need more of all forms of energy and so we would simply suggest that government not pick winners and losers either among all of the various types of alternative fuels or between alternatives and conventional fuels. However, if government decides to favor a particular fuel source, it should not do so at the expense of other energy supply sources because such an approach is likely to result in less total energy supplies rather than more. See further our response to question 39.

(13) Do you support suspending or reducing the number of "boutique fuel mixes" that each state mandates in order to reduce gas prices in the near future?

A: Boutique fuels decrease supply flexibility and potentially increase price volatility in times of supply disruption.

Suspending or reducing the number of boutique fuels would reduce the potential for price volatility during supply disruptions, but would be unlikely to significantly impact fuel prices under normal circumstances.

(14) Do you believe that the Energy Independence and Security Act of 2007 went far enough to access US oil and natural gas resources?

A: No. The 2007 energy legislation did not address the need for increased access to America's abundant oil and gas resources that are now "off limits" to development. Neither did the Energy Policy Act of 2005 in any meaningful way, despite urgent calls since early this decade for authorizing legislation to expand access to the most prospective areas in federal lands and waters for discovering potentially commercial quantities of oil and natural gas.

(15) Are you actively pursing carbon sequestration and Enhanced Oil Recovery in your oil fields and has that work been successful? What more needs to be done in this area?

A: ExxonMobil has been researching, developing and applying carbon-handling technologies for more than 30 years. We have studied a wide range of technologies that may be applicable to CCS; including computer based geologic reservoir simulation improvements to surface facility and wellbore integrity through the use of advanced materials and operating practices, and the development of more efficient CO_2 capture technologies.

CCS is a promising option in managing GHG emissions, particularly as many companies, including ExxonMobil, have industrial-scale experience with its three component technologies, capture, transport and storage. With nearly 60 percent of global fossil fuel CO_2 emissions coming from large point sources, such as electricity generation plants, CCS applied to such facilities offers the potential to address a significant fraction of global emissions. However, large scale application to facilities, such as electricity generation plants, remains to be fully demonstrated. In addition to the integration of the three components, significant improvement in the energy efficiency of the CO_2 capture process is needed. The U.S. DOE currently estimates that for post-combustion capture of CO_2, up to 30 percent of a coal fired power plant's generating capacity will be required to power the capture process. For pre-combustion capture, processes are slightly more efficient but are still estimated to require up to 25 percent of a coal fired power plant's generating capacity.

All ExxonMobil oil and gas fields are managed to maximize economy recovery of resources, including the use of a wide range of enhanced oil recovery (EOR) technologies such as gas injection — which can employ hydrocarbon gas, carbon dioxide or nitrogen — chemical injection using polymers, surfactants or alkalines and steam injection, which is particularly well suited to heavy oil EOR. We also recover CO_2 from produced gas and market it to others for use in their EOR operations.

No single EOR technology (including CO_2 injection) is universally applicable. EOR opportunities depend on factors such as infrastructure, reservoir properties and field development plans, but incremental recovery from carbon dioxide injection at some mature fields can range from five to fifteen percent of the original oil in place.

ExxonMobil has significant experience in EOR processes through its involvement in about one-third of the world's oil production from miscible gas injection EOR projects. We leverage that experience along with various in-house technologies into all of our EOR projects. The most successful example of CO_2 based EOR is in the mature oil fields of the Permian Basin of West Texas, where significant investment by ExxonMobil and others have resulted in EOR projects that have recovered an additional one billion barrels of oil, that would not have otherwise been produced. Approximately a quarter of today's production in the Permian Basin, 250,000 barrels of oil per day, is generated by CO_2 based EOR. The effectiveness of CO_2 EOR in West Texas suggests that CCS could have a significant positive impact on future energy supplies while providing early opportunities for the reduction of GHG emissions. CO_2 based EOR currently accounts for five percent of U.S. oil production. An important feature of this production, however, is that the CO_2 is sourced from naturally occurring gas reservoirs, and not from separation from industrial waste gases.

Knowledge gained from fundamental studies, laboratory measurements of reservoir conditions, detailed geologic and simulation modeling and field pilot testing are integrated to develop new EOR technologies to substantially improve recovery and economic performance. All EOR processes have common challenges including the fundamentals of phase and flow behavior, fluid and rock compatibility, mobility control, and the scale-up of EOR process technology from the laboratory to the oil field. ExxonMobil maintains an active research program to understand and develop new EOR processes focusing on these issues.

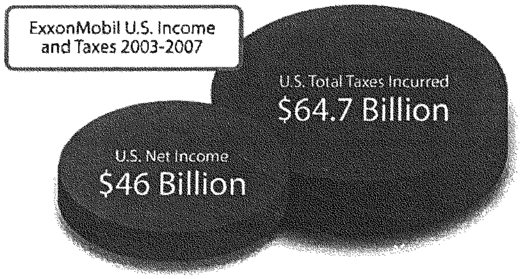
One of the best-known and longest-running CCS projects is in the Sleipner Field in the North Sea - in which ExxonMobil shares ownership (32.24 percent working interest). The project has stored ten million metric tons of CO_2 over the last decade. Our company is working with the European Commission and other companies on the CO2ReMoVe project to evaluate a range of carbon injection and storage technologies in Norway, Algeria and Germany.

ExxonMobil also recently announced that we are committing more than $100 million to complete development and testing of an improved natural gas treating technology for CO_2 removal called Controlled Freeze Zone^{TM} technology (CFZ^{TM}) that could make CCS more affordable and significantly reduce GHG emissions. As part of this program, ExxonMobil is building a commercial demonstration CFZ^{TM} plant near LaBarge, WY. In addition, ExxonMobil is participating in the U.S. Department of Energy's Southeast Regional Carbon Sequestration Partnership and supports CCS research at the International Energy Agency's Greenhouse Gas Research & Development Program, and programs at leading universities, including Massachusetts Institute of Technology, Georgia Tech, the University of Texas and Stanford University. In Australia, ExxonMobil with its joint venture partners in the Gorgon LNG Project is pursuing the largest commercial scale CCS project in the world. To date, the Gorgon CCS project represents the biggest single investment contemplated solely for the management of GHG emissions.

CO_2 storage / EOR is a near-term opportunity for initiating CCS, but it is not the long-term solution. Large scale demonstration of CCS in a coal fired power plant application is one of the most significant technology development and application challenges. Successful demonstration of CCS for these large scale applications will build public and investor confidence and allow CCS to move forward. In general, economic, legal and regulatory clarity and certainty are required before widespread commercial implementation of CCS will occur. The level of monetary investment necessary for meaningful CCS will be substantial, possibly reaching levels anticipated for energy development during this same time. The amount of physical infrastructure projected to be necessary to have a significant effect on atmospheric GHG concentrations will be similar to that which exists today for the production and transportation of oil and gas. Capture facilities will roughly double the current "footprint" of power plants and require a significant fraction (20-30 percent) of the plant's power output just for capture operations. A key determinant in making these investments will be the nature of the economic, legal, and regulatory environments.

(16) What is a ballpark figure of how much your company pays in taxes each year?

A: In 2007, ExxonMobil's worldwide tax expenses amounted to over $105 billion. From 2003 - 2007, our U.S. tax bill ($64.7 billion), including all forms of taxation, ***exceeded*** our U.S. earnings ($46.0 billion) by almost $19 billion.



(17) A couple of you mentioned the National Petroleum Council report "Facing the Hard Truths about Energy" do any of you disagree with the findings of that report?

A: ExxonMobil supports the overall findings and recommendations contained in that Report. The Council advised:

a) Global energy demand is likely to grow significantly over the next 25 years, with forecasts generally in the range of 50–60 percent growth by 2030 over 2000.

b) Fossil fuels will remain indispensable to meeting total projected energy demand growth. Even with assumptions for dramatic growth in solar, wind, and biofuels, fossil energy is generally forecast to continue to supply roughly 80 percent of the world's energy needs through 2030.

c) The world is not running out of energy resources, but there are accumulating risks to continuing the expansion of oil and natural gas production from conventional resources, primarily due to geopolitics rather than depletion; and these risks create significant challenges to meeting projected future energy demand.

d) "Energy independence" for the U.S., and for most countries, is not realistic in the foreseeable future. Furthermore, energy independence is not synonymous with energy security. There can be no U.S. energy security without global energy security.

e) The majority of the U.S. energy workforce, including skilled engineers and scientists, is eligible to retire within the next decade — the need to train replacements poses a significant challenge.

f) Policies aimed at curbing carbon emissions will require altering the energy mix, increasing energy-related costs, and reducing growth in energy demand.

While the NPC's recommendations focus on the U.S., they can be broadly applied to other countries as well. Among the policy strategies recommended to address these "hard truths" were the need to:

a) Moderate the growing demand for energy by increasing the efficiency of transportation, residential, commercial, and industrial uses.

b) Expand and diversify energy production from clean coal, nuclear, biomass, other renewables, and unconventional oil and natural gas; moderate the decline of conventional domestic oil and gas production; and increase access for development of new resources.

c) Integrate energy policy into trade, economic, environmental, security, and foreign policies; strengthen global energy trade and investment; and broaden dialogue with both producing and consuming nations to improve global energy security.

d) Enhance science and engineering capabilities and create long-term opportunities for research and development in all phases of the energy supply and demand system.

e) Develop the legal and regulatory framework to enable CCS. As policymakers consider options to reduce carbon dioxide emissions, provide an effective global framework for carbon management, including establishment of a transparent, predictable, economy-wide cost for carbon dioxide emissions.

(18) Several of you mentioned the increasing cost of materials, difficulty in finding labor and specifically difficulty in finding engineers and scientists in oil and gas development. What policies do you think would help get the materials and people that you need?

A: ExxonMobil relies on technology and innovation in every aspect of our business, and knowledge of math and science is critical in the energy sector. We employ approximately 15,000 scientists and engineers to help produce and deliver energy supplies safely, reliably, and affordably. The technological innovations necessary to facilitate human progress and meet key challenges in the years ahead will require a global workforce highly skilled in fields making use of math and science.

Excellence in math and science education is directly correlated to the ability of countries to successfully compete and prosper in the global community of the 21st century. For example, the United States ranks behind other countries in terms of the proportion of students who perform well in math and science and pursue degrees in these subjects. Many math and science teachers in the United States do not have the benefit of strong content knowledge and training specific to the subjects they teach.

In 2007, ExxonMobil continued investing heavily in math and science education in the United States. We supported initiatives that encourage students to take an active interest in careers in the math and science fields, support the professional development of highly qualified teachers, and promote involvement of women and minorities in these subjects.

ExxonMobil became a founding sponsor of the National Math and Science Initiative (NMSI) in 2007 and committed $125 million to support the Initiative, the largest-ever corporate gift for math and science education in the United States. NMSI is a nonprofit organization that facilitates the national scale-up of programs that have a demonstrated impact on improving math and science education.

See attached op-ed published in the New York Times on September 4, 2008 in which NMSI urges government to support the math and science education movement by funding the COMPETES Act passed earlier this year.

(19) Is there something in the manufacturing sector that we need to do to help insure that you get the supplies that you need?

A: Many domestic manufacturers, including ExxonMobil, support increased access to America's domestic oil and natural resources in order to expand supply diversity, improve our energy security, and increase supplies of critical energy feedstocks, with the potential therefore to lower the costs of these commodities.

(20) The International Energy Agency estimates that $22 trillion in new energy investments will be needed by 2030. Where would that money come from?

A: Presumably, the massive investments needed to meet the world's growing energy needs, to sustain global economic growth, would come from multiple sources. These would include investments by publicly-traded independent companies, individuals, governments in some cases, and nationally-owned companies.

(21) What would be required to get biofuels to a commercial scale that they could replace oil in the United States?

A: ExxonMobil, EIA and many others believe that oil and gas will continue to play a significant role in meeting energy demand for many years to come, and that biofuels alone will not replace oil for the foreseeable future even if significant technological breakthroughs occur.

(22) In your testimony, several of you point to speculation as a contributing cause of high crude oil prices. I have introduced legislation, the Prevent Unfair Manipulation of Prices (PUMP) Act (HR 594), which would improve oversight of "dark markets" which are currently unregulated by the Commodity Futures Trading Commission. In our December 2007 Oversight and Investigation Subcommittee hearing, we heard testimony that this could reduce the cost of oil by $30 a barrel. Do you believe that speculation in the market is driving up the price of oil? Would you support this legislation?

A: Crude oil prices are influenced by a multitude of factors. These include physical and fundamental factors, such as supply, demand, inventory, and spare capacity, as well as expectations of the market participants on such matters as potential weather-related effects and outlooks on the growth of supply, demand, and capacity. In addition, crude oil prices can be affected by currency exchange rates, geopolitical risks, and actions of investors and financial institutions. It is not possible to identify definitively the impact of individual factors on crude prices.

ExxonMobil has reviewed the provisions of the Prevent Unfair Manipulation of Prices (PUMP) Act - HR 594. There should be no tolerance for acts of illegal or fraudulent market manipulation, and there are laws already enacted which would punish those who engage in illegal or fraudulent market manipulation. The FTC is currently engaged in a rule making process which will address market manipulation. The FTC process is underway consistent with the authority it was granted by the provisions of the EISA 2007. Until the FTC rulemaking process is complete, we think it is premature to consider additional legislation, including the PUMP Act.

(23) What is the average number of barrels of oil your companies trade each day on NYMEX? On the InterContinental Exchange (ICE)?

A: ExxonMobil's use of derivatives is de-minimus and accounts for less than ~2 percent of our total physical trading volume. In 2007, about 150 Kbd of oil was traded through NYMEX and approximately 25 Kbd was traded through ICE. ICE is used primarily for simultaneous conversion of Brent priced cargoes to a WTI pricing basis for cargoes destined for the U.S. Use of ICE avoids two separate transactions involving ICE and Brent since Brent is not traded on NYMEX. ICE is also used to hedge exposure on fixed price heating oil sales to European customers. ExxonMobil does not use derivatives for speculation.

(24) During the April 1, 2008 hearing, you each spent most of your time complaining about taxes, specifically that the Renewable Energy and Energy Conservation Tax Act (H.R. 5351) passed by the House would repeal $18 billion over ten years in subsidies to your companies. Several times during the hearing, you also said that your companies do not support mandates and subsidies for renewable fuels. Over the next ten years, your companies are expected to make $14.6 trillion. H.R. 5351 would only account for approximately one tenth of one percent of your gross income! How can you insist on retaining these subsidies and tax breaks for your companies while opposing assistance for renewable energy?

A: First, we appreciate the opportunity to address the facts behind the Domestic Manufacturing deduction (found under §199 of the Tax Code) because there have been so many mischaracterizations of this issue.

As background, The American Jobs Creation Act of 2004 provided new tax rules for all U.S. manufacturers and producers. While this legislation began as an effort to modify the Extraterritorial Income Exclusion (ETI) tax rules declared illegal by the World Trade Organization, Congress expanded that goal to include the creation and retention of U.S. jobs throughout the critical domestic manufacturing and production sector, including, of course, jobs in the U.S. oil and natural gas industry. Promoting jobs in America continues to be a priority embraced by many in Congress today, and thus, repealing this provision at this time, in whole or in part, would be at odds with that goal.

Congress had not reduced the U.S. corporate income tax rate since 1986, despite rate cuts enacted by many other nations. Section 199 addressed this for U.S. manufacturers and producers since, when fully phased in, the §199 deduction will be approximately the equivalent of a three percentage point reduction in the corporate income tax rate for all qualified domestic manufacturing and production income.[1]

The §199 provision applies to all manufacturing activities in the U.S., i.e., it is not a provision designed solely for the oil and gas industry, or only for large companies in the oil and gas industry. Characterizing this general provision as an "oil company subsidy" or as a "tax break for big oil" is highly misleading to the public. Repealing this provision only for U.S. oil and natural gas producers and refiners, or worse, only for five companies operating in that business, while maintaining it for all other manufacturers and producers, would simply single out one industry, or worse, five companies within an industry, for unjust, punitive and arbitrary treatment. That is highly discriminatory and unsound tax policy.[2] And the result would be to discourage critical new oil and gas investments here in the U.S., by making those already costly domestic energy investments even more costly and thus less competitive with foreign opportunities.[3] In the refining sector, U.S. industry margins in the first half of 2008 fell dramatically from the first half of 2007. Given these current conditions for the U.S. refining business, and the call of many in Congress for increased refinery capacity, it is perplexing that some members of Congress would continue to propose increasing taxes on such investments.

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[1] The provision was "phased in" over several years, starting with the approximate equivalent of a 1% rate reduction for 2005 and 2006, a 2% rate reduction for 2007-2009, and finally the 3% reduction beginning in 2010.

Investments in oil and gas exploration and development projects require a long-term commitment of massive amounts of capital. As we all have seen, the oil and gas business is a highly cyclical one, and the fact that prices are high at the current time is no guarantee that they will stay that way throughout the 20-30 years of the project life. One need only look back over the last 20-30 years, and the predictions made during that period, to see the volatility of prices and the inaccuracy of predictions based on such prices.

The issue, then, is not whether sufficient capital exists to invest in such projects. It does, within our company, within our industry, and within the capital markets that oil and gas companies may access. But the question is whether the investor has a reasonable prospect, taking into account the huge uncertainties associated with such investments, to realize an acceptable return over the project life for undertaking such risks. Adverse changes to tax laws, which when originally enacted were intended to encourage certain investments, not only reduce the returns on such investments after the fact but inject even more uncertainties and risks for potential investors considering future projects. And increasing taxes on U.S. oil and gas investments will result in less domestic investment, and ironically, even greater reliance on foreign imports.[4]

According to a recent study by PricewaterhouseCoopers, the oil and natural gas industry employed 1.86 million wage and salary workers in the United States in 2004.[5] In addition, the industry's purchase of goods and services from other industries supported nearly 4.1 million indirect and induced jobs across the country, resulting in nearly 6 million jobs as the total employment contribution of the oil and natural gas industry to the U.S. economy. Oil and gas extraction activities are found in 42 states.

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[2] Interestingly, out of 78 oil and gas companies operating worldwide, the five companies singled out by the Senate for such treatment were ranked 42, 53, 57, 60, and 63 in terms of profitability based upon profit margin. See Energy Intelligence Research: The Energy Intelligence Top 100: Ranking the World's Oil Companies, 2008, p. 85.

[3] In the U.S., the most promising exploration and development projects are increasingly found offshore. According to the Energy Information Administration, it costs U.S.-based oil and gas companies about 20 percent more to explore for and produce a barrel of oil or equivalent natural gas in the United States than abroad.

[4] See the Congressional Research Service's *CRS Report for Congress: Energy Tax Policy: History and Current Issues, Updated April 1, 2008*, which, in addressing the effect of the Section 199 repeal, states: "Domestic oil and gas output would be lower, and imports would be higher than they otherwise would be without the tax increase." Page 20.

[5] *The Economic Contributions to the U.S. National and State Economies by the Oil and Natural Gas Industry*, PricewaterhouseCoopers, January 15, 2007, Table 4, p. 9.

These are high-paying jobs for middle-class Americans, paying more than three times the current minimum wage for non-supervisory workers. Encouraging greater investment in domestic oil and gas operations in exactly the same way as for all other domestic manufacturers and producers helps keep more Americans working in these valued occupations.

U.S. energy security is clearly enhanced by greater investment in domestic oil and gas activities. According to projections by the EIA in its *Annual Energy Outlook 2008*, domestic crude oil production is expected to rise slightly through 2020 before declining in the 2020–2030 timeframe. Increased access to available resources and a reliable fiscal and regulatory investment framework will be critical to sustain domestic production over the long term and reduce U.S. reliance on imported oil.

In order to provide adequate supplies of energy for American consumers, U.S. oil and natural gas companies must seek out the most cost-competitive sources of oil and natural gas available to them. Retaining §199 for the domestic oil and gas industry, and keeping those investments on a par with all other domestic manufacturing and production activities, will maximize domestic oil and gas investment and jobs, and reduce foreign imports.

(25) At the American Society of Newspaper Editors Convention on April 14, 2005, the President said, "I will tell you, with $55 [a barrel] oil we don't need incentives to oil and gas companies to explore. There are plenty of incentives. What we need is to put a strategy in place that will help this country over time become less dependent. It's really important. It's an important part of our economic security, and it's an important part of our national security." Today, crude oil prices are double the President's example! Do you agree with President Bush that oil and gas companies do not need incentives to explore when oil is more than $55 a barrel? Do you agree with President Bush that we should instead be investing in renewable energy that will help this country become less dependent on oil?

A: ExxonMobil did not support or seek new incentives for energy production in the Energy Policy Act of 2005, which, contrary to the assertions of many commentators, resulted in a net tax increase for our company and for the oil and gas industry. See CRS Report for Congress-- Order Code: RL33763, February 27, 2007 page CRS-14 footnote b, which states: "Energy tax increases comprise the oil spill liability tax and the Leaking Underground Storage Tank financing rate, both of which are imposed on oil refineries. If these taxes are subtracted from the tax subsidies (row 2), the oil and gas refinery and distribution sector received a net tax increase of $1,356....." million. The one benefit in EPACT05 for the oil and gas production sector, amortizing G&G costs over two years, which was less than the $1.4 billion cost on the refining sector, has since been reversed in its entirety for integrated producers like ExxonMobil. ExxonMobil agrees that the world will need growth in all forms of energy, including oil and natural gas, to meet the needs of billions of people, particularly in the developing world, who aspire to be lifted out of poverty in coming decades.

(26) I have attached internal memos from Chevron, Texaco, and Mobil. The Chevron memo quotes a "senior energy analyst at the recent API convention," stating "if the U.S. petroleum industry doesn't reduce its refining capacity it will never see any substantial increase" in profits. The Texaco memo complains that "supply significantly exceeds demand" leading to "very poor refinery margins and very poor refinery financial results." The Mobil memo advocates keeping a smaller refiner, Powerine, from reopening, stating that a "full court press is warranted in this case." From 1995 to 2002, more than 30 refineries have been closed in the United States. Have any of your companies applied for permits to build new refineries? If yes, how long did it take to obtain the necessary permits? In July 2007, gas prices increased 30 cents overnight in Escanaba, Michigan. There were no supply disruptions or other major events that would influence the price this significantly. Is there any logical explanation why prices would increase 30 cents in that short of time? On May 23, 2007, the U.S. House of Representatives passed H.R. 1252, the Federal Energy Price Gouging Prevention Act by an overwhelming vote of 284 to 141. Please explain why this legislation is not needed, given the significant price increases consumers continue to face.

A: Since 1995, ExxonMobil has expanded its worldwide refining capacity at a rate equivalent to building a new, average-size refinery every three years. Much of this expansion occurred in the U.S. Expanding existing refineries is generally faster and less costly than building new refineries. Because ExxonMobil has focused on expanding existing refining capacity, we have not applied for permits to build any new refineries in the U.S. in the last decade.

ExxonMobil's participation in the Escanaba, MI market is minor and does not include any direct-served retail stations. ExxonMobil sells and delivers motor fuels to branded distributors at a bulk distribution terminal in Green Bay under supply agreements at "rack" prices, and these prices are established based primarily on local competitive conditions. These distributors either resell the product to their own franchisees or supply it to their own company-operated stations. ExxonMobil does not set the retail price at distributor-served stores.

ExxonMobil's rack prices at the Green Bay terminal at the end of July 2007 were within 14 cents per gallon of its rack prices at the beginning of the month. Prices did fluctuate throughout the month, at one point reaching a high of nearly 51 cents per gallon above the month low. There were a number of factors, clearly documented by the EIA and others, that may have contributed to price volatility during this period including inventory levels, increased demand and unplanned refinery outages. ExxonMobil does not have any refineries in Michigan and none of the unplanned outages occurred at an ExxonMobil refinery in the region.

With respect to the Federal Energy Price Gouging Prevention Act (HR 1252), ExxonMobil does not engage in or condone price gouging. The majority of Exxon and Mobil branded retail stations are operated by individual dealers and distributors who independently determine the retail prices they charge at their stores. The price increases which consumers have seen in recent months are a function of transparent and free-functioning markets. Those same free-functioning markets reflect the dynamics of supply and demand that have resulted in decreases in crude oil and retail gasoline prices in the last few weeks. ExxonMobil believes that anti-price gouging laws are unnecessary and can have unintended consequences by introducing ambiguous controls that could confuse and slow beneficial market responses to supply fuels during disruptions such as those caused by weather events.

(27) In May 2004, the U.S. General Accounting Office released its report, "Effects of Mergers and Market Concentration in the U.S. Petroleum Industry." In this report, GAO found that over 2,600 mergers have occurred in the U.S. petroleum industry since 1990. The GAO also pointed to economic literature that suggests that firms sometimes merged to enhance their ability to control prices. Each of your companies today is the result of significant mergers in the industry. Do you see any more mergers taking place?

A: We believe that recent consolidations in the U.S. refining sector have improved the efficiency of U.S. refining, placing it in a stronger position to compete in the worldwide petroleum marketplace. In our own merger, we have seen improvements from sharing the best practices of each of the parent companies with the refineries of the other. Several refineries have been sold to independent/smaller refiners as part of FTC conditions for allowing mergers to proceed. For example, independent refiner Valero is now the largest U.S. refiner.

We believe that consolidations in the U.S. refining sector have improved the efficiency and capacity of U.S. refining, thus benefiting consumers. In the last decade, refinery capacity has grown significantly, as has the production of refined products.[6] U.S. refineries add the equivalent of one new refinery each year through expansion of existing facilities.[7] After significant restructuring in the industry, concentration of refining capacity is not at a level that gives rise to market power concerns — regional and national concentration levels are generally low to moderate.

ExxonMobil does not know whether more consolidation of firms will occur in the future.

(28) In your testimony, almost all of you mention "more domestic drilling" as your top solution to high energy prices. What assurance can you provide that oil and gas from the Arctic National Wildlife Refuge (ANWR), the Outer Continental Shelf (OCS), or other domestic sources would stay in the United States? What is your response to economists that tell us that the oil and gas will likely go to higher priced markets in Japan and elsewhere?

A: Currently, the United States consumes almost all of the oil and natural gas it produces, according to the EIA.

- In 2007 the United States exported 10 million barrels of crude oil out of a total U.S. production of 1.8 billion barrels.

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[6] *See* Energy Information Administration, ANNUAL ENERGY REVIEW 2006, at page 141, Table 5.9 (Refinery Capacity and Utilization, Selected Years 1949-2006); Timothy J. Muris and Richard Parker, A DOZEN FACTS YOU SHOULD KNOW ABOUT ANTITRUST AND THE OIL INDUSTRY 44.

[7] Muris and Parker, *supra* note 2, at 26.

- In 2007 the United States exported 822 million cubic feet of natural gas, out of a total U.S. production of 24.5 trillion cubic feet.

Economic nationalism in the form of protectionism hinders international market progress, invites countermeasures, and ultimately harms the people in the nations adopting such policies. The fact is we live in a connected world, and it is becoming more so every day. When prices are high and supplies tight, passions can run high. Oil importing nations can feel the pressure to assert their independence, as can oil exporting nations. On both sides, economic nationalism may gain in popularity, at the expense of international market progress, and ironically, hurting those that it seeks to protect.

The path to energy security – in this or any other country -- lies in open, competitive markets, international trade, diversity of supply, and the strengthening of relationships between producing and consuming nations. The value of such an interconnected marketplace is that energy security is enhanced when there are more participants, better relationships, and more diverse sources of supply.

The U.S. depends upon oil imports to meet approximately 60 percent of its oil requirements. If importing nations diversify their sources of energy, strengthen their partnerships with exporting nations, and develop and use their resources more efficiently, they will become less dependent on any one country or region for energy. Removing barriers to trade, improving access to resources, and opening markets to free competition will help minimize potential disruptions.

(29) In May 2006, the Energy and Commerce Committee held a hearing on gas prices, and we discussed the crack spread, or the difference between a barrel of crude oil and the refined product. At this hearing, the average crack spread for a refinery in 2006 was estimated to be about $20 to $30 a barrel by Howard Gruenspect, the Deputy Administrator at the Energy Information Administration. Mr. Gruenspect testified that a crack spread of $8 or $9 is sufficient to cover refining expenses and provide a reasonable profit to the facility. What is your current crack spread at the refineries your companies operate? Why have your companies scaled back their refinery expansion plans to keep crack spreads high?

A: ExxonMobil has not scaled back its refining expansion to keep crack spreads high. As noted above, ExxonMobil has been increasing its refining capacity by expanding its existing refineries. ExxonMobil does not comment on its current refining economics.

(30) Please provide a list of oil and gas leases currently in the possession of your company and its subsidiaries, and give a status report as to the state of the production of each of these leases.

A: We have compiled the following summary data. In reviewing the lease data, however, it is important to note that these figures provide only a snapshot in time of ExxonMobil's holdings.

Currently, ExxonMobil is either producing on or actively evaluating 78 percent of our Federally-leased acreage. The majority of the remaining leased acreage is projected to expire within the next 12 months.

ExxonMobil has made significant bonus payments to the Federal government to acquire these leases and pays annual rentals to maintain them. We also invest millions of dollars in exploration costs in our efforts to find commercial quantities of oil and natural gas. If oil and natural gas are not discovered within the lease term, the lease reverts to the government for re-leasing and ExxonMobil forfeits all the money invested. Thus, ExxonMobil has a strong financial incentive to develop these leases and commence production as quickly as possible.

ExxonMobil currently holds 2.7 million net acres in leases on federal lands. Of this, 68 percent (1.8 million net acres) is located offshore and 32 percent (854 thousand net acres) is located onshore. Forty nine percent (1.3 million net acres) is categorized as *producing*, and 29 percent (785 thousand net acres) is categorized as *nonproducing – active.*

We have identified *nonproducing – active* acreage by using the following definition:

Activities that include, but are not limited to, mapping and surveys, surface and subsurface geological/geophysical examinations, investigations and studies (including acquisition, reprocessing, and interpretation from seismic, gravity, or magnetic surveys), obtaining and analyzing well data via trading, purchasing and/or the drilling of wells (including wildcat and appraisal wells), and all work necessarily conducted therewith (e.g. land activities such as negotiating farm outs, joint ventures and acreage trades, etc.) as well as regulatory activities such as permitting, evaluation of archeological and biological suitability for well locations, etc.

The remaining 22 percent of ExxonMobil's federal lands (589 thousand net acres) is categorized as *nonproducing — no current activity.* More than 80 percent (483 thousand net acres) of the *nonproducing — no current activity* acreage is located in the Gulf of Mexico and is projected to expire by the end of 1Q 2009, at which time it will be available for re-leasing under future MMS Gulf of Mexico lease sales. This acreage has been under evaluation for some time using technology such as seismic acquisition and processing, regional geologic studies and lease-specific geologic mapping. This work led to the conclusion that these leases do not likely contain commercial quantities of oil and/or natural gas and therefore we have taken the decision to allow the leases to expire.

The portion of ExxonMobil's acreage portfolio which is inactive and does not expire in the near term — which is only 4 percent of ExxonMobil's Federal leases — is also located largely in the Gulf of Mexico. This acreage has been evaluated through geologic and geophysical studies and the conclusion we have reached is that the prospectivity of these leases is low or exceedingly risky and therefore, for now, we have ceased activity on them. While currently not active, new data and / or exploration concepts may lead to a change in our perspective and revitalization of activity.

ExxonMobil believes that the United States needs to allow the oil and gas industry to bring to bear the full range of its technological advances to develop to the fullest extent the country's domestic resources to help meet the nation's growing demand for energy and sustain our economic growth. Legislative and regulatory actions that would suspend new leasing to most or all lease holding companies, add costs, and undermine contract sanctity, would prevent new investment and shrink the nation's energy supply. Oil and gas is a global business and the United States already has the largest barriers to its own energy resources. It seems unconscionable to consider policies that would make a bad situation worse sending more investment and jobs overseas and reducing energy security.

The problem is not that companies are ignoring the leases they have but, rather, that companies do not have access to some of the most promising federal acreage and, as a result, are struggling to find new oil and gas supplies from the limited offerings of the last 10 years. The United States now imports approximately 60 percent of its supply from other countries (many of whom allow exploration and production activities on substantially all of their lands) while prohibiting access to nearly 90 percent of the acreage off of the East and West coasts and Gulf of Mexico. The continuation of ill-advised policies that preclude access to prospective acreage will accelerate the current decline in domestic oil and gas production. It also forgoes the building of a more diverse domestic supply to maximize the United States' energy security.

Our economy needs affordable energy supplies to compete in the global marketplace. Therefore we strongly believe that our companies must be allowed access to areas that may have the potential to produce the oil and natural gas consumers will need. The oil and natural gas from federal leases that are producing today are a result of the foresight of Congress in years past. The appropriate question to be answered by this Congress is "where do we want to be ten years from now?"

(31) As fuel prices rose over the past 6 years, has American demand decreased? Why or why not has this occurred? If gas taxes were increased, do you think demand would decrease? Did this happen in European countries when then imposed large gas taxes?

A: According to the EIA, demand for crude oil and petroleum products increased from 19.8 MBD in 2002 to 20.7 MBD in 2007. Over the same period, motor gasoline demand increased from 8.8 MBD to 9.3 MBD.

Decreased demand for petroleum products in general and gasoline in particular has only been consistently evident in the past year. According to EIA data, sustained year-on-year reductions began late 3Q 2007.

Why or why not has this occurred?
Demand for petroleum products is determined by many factors including economic progress and rising population as well as price. As energy is essential to our way of life, demand is fairly inelastic to price, particularly in the short term. Gasoline is a good example of petroleum demand inelasticity.

Until recently, the positive income effect of economic growth has dominated the negative price effect resulting in a continued demand increase from 2002 to 2007. However, as the U.S. economy slowed down in late 2007, the positive income effect has been smaller. At the same time, high gasoline prices have been exerting a more significant negative price effect. The combination has contributed to the recent reduction of gasoline demand.

If gas taxes were increased, do you think demand would decrease?
Ultimate energy demand and market prices are determined by many factors with taxes being just one element. However, all else being equal, raising gas taxes would result in higher gasoline prices and potentially work to reduce demand subject to the nature of the tax increase.

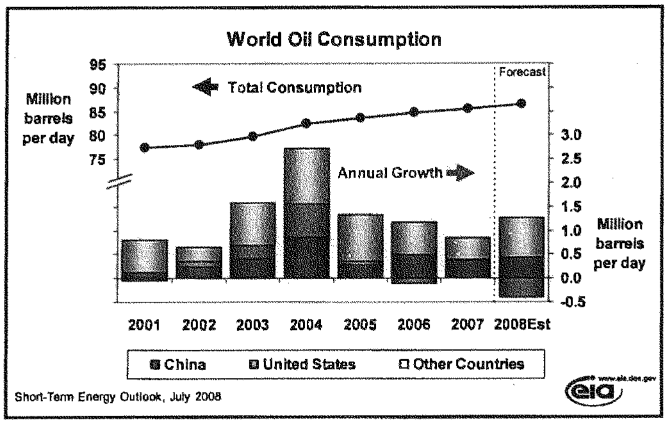
Did this happen in European countries when they imposed large gas taxes?
Fuel demand for commercial and personal transportation is determined by many factors with taxes being just one element. However, substantial taxes on fuels in Europe, including gasoline, have been a contributing factor in moderating demand growth.

(32) At current projections, when will your current reserves be depleted?

A: Our exploration programs have consistently added to our resource base and we expect will continue to add resources in the future. Based on 2007 oil equivalent data, our proved reserves base of over 22 billion barrels is equivalent to over 14 years of production at 2007 levels. This ratio of proven reserves to production has increased every year since 1994, as we have consistently added to our reserve base. Our total resource base of 72 billion barrels is equivalent to over 45 years of production.

(33) When do you expect underdeveloped countries will reach a level to where they will begin to significantly buy oil for use? How will this affect supply and fuel prices?

A: While a specific answer would depend on one's definition of "undeveloped countries," it is a fact that world oil consumption continues to grow, following seven consecutive years of rising prices, primarily from growth in China and other developing countries. The graphic below illustrates this growth, which has been an important factor in increasing global oil prices.



Short-Term Energy Outlook, July 2008

The U.S. Energy Information Administration preliminary data indicate that world oil consumption during the first half of 2008 rose by roughly 520,000 barrels per day compared to 2007. A 1.3 million barrel per day increase in non-OECD countries, led by China and the Middle East, more than offset a 760,000 barrel per day decline in OECD countries.

ExxonMobil projects that future energy demand will grow fastest in the developing world (non-OECD countries) in the coming decades, accounting for approximately 80 percent of the global increase.

(34) If all conventional, alternative, and unconventional sources of oil in the U.S. were to be developed, how long would the supply last based on current estimates of increased usage?

A: The U.S. Department of Interior estimates that all federal lands, including those on the Outer Continental Shelf (OCS), hold an estimated 116 billion barrels of recoverable conventional oil and 650 trillion cubic feet of recoverable natural gas. According to the American Petroleum Institute (API), this is enough oil to produce gasoline for 65 million cars for 60 years and enough natural gas to meet the heating needs of 60 million households for 160 years. And hydrocarbons are not only the foundation for fuels, they are also the basis for a myriad of products such as advanced plastics that are key to improving quality of life and reducing the environmental impacts of our vehicles, regardless of their source of fuel.

However, it is important to note that these resource estimates are just that - estimates - and particularly in the case of the OCS, the estimates were made using data acquired pre-1980 from now-obsolete technology. In 1987, the MMS estimated that there were 9 billion barrels of oil in the Gulf of Mexico. By 2006, after major advances in seismic technology and deepwater drilling techniques, the MMS resource estimate for that area had ballooned to 45 billion barrels. Therefore, it is very possible that there are significantly more resources than currently estimated on federal lands. However, the real potential and location of the resources will only be known after new seismic is carried out.

According to the Bureau of Land Management (BLM), U.S. oil shale deposits contain an estimated 1.23 trillion barrels of oil - more than 50 times the nation's proven conventional oil reserves. U.S. tar sands deposits are estimated to hold an additional 12 to 19 billion barrels of oil.

(35) Please describe to this committee your short, middle, and long-term plans for oil and renewable energy development.

A: Enclosed please find the ExxonMobil 2007 Financial and Operating Review, in which we address energy and technology trends, articulate our capital investment philosophy (at page 34), a listing of Major Project Start-ups around the world, and regional review of key investments.

(36) Which tax policies do you find particularly important as you develop oil and natural gas resources?

A: The most important tax policies for development of oil and gas resources are those that are applicable to all U.S. taxpayers-- that is, long-term stable tax provisions that are impartial, non-discriminatory and that promote, or at least don't disadvantage, the competitiveness of U.S. based companies. This is why we have objected to the singling out, for punitive tax treatment, of five companies by repealing, just for them, a provision put in place only 4 years ago which was designed to promote U.S. jobs. How can any taxpayer rely on such expressions of Congressional intent if they are reversed before they have a chance to have the impact that Congress said was desired? These provisions apply equally to all U.S. manufacturers and producers, and targeting five companies, and suggesting that this provision is something unique to them, and needs to be "taken back", is highly arbitrary, unsound, and unwise tax policy. It hardly promotes confidence that any taxpayer can rely on provisions ostensibly enacted to encourage certain activities when they are reversed in such an arbitrary fashion.

We are equally concerned about the proposed changes to the foreign tax credit rules applicable to U.S. based oil and gas companies operating abroad. Those companies already face more restrictions than any other U.S. business enterprise with respect to their foreign operations. If anything, the rules should be conformed to treat all U.S. taxpayers engaged in business operations outside the U.S. in the same way. But changing them as proposed in order to raise revenues without any justification that has been published and that taxpayers have been able to comment upon is, again, improper and unsound tax policy. These provisions, if enacted, will make U.S. companies less competitive than their foreign counterparts, and this can hardly be a benefit to the country.

We would finally point out that much has been made about expressions regarding tax incentives to the oil and gas industry provided under the Energy Policy Act of 2005, or EPACT05. There was one provision in EPACT 05 that favorably affected integrated oil and gas production activity. There were some additional provisions that favorably affected oil and gas refining and distribution activities, but these were more than offset by energy tax increases on the oil refining sector such that the act actually resulted in a net tax increase to that sector of over $1.3 Billion. The only favorable oil and gas production sector provision was reversed in 2006, and made even less favorable in 2007 for integrated oil and gas companies. It is particularly ironic that politicians keep talking about "taking away" the incentives given to the oil and gas industry under EPACT05, when from the beginning they amounted to a net increase in taxes on the oil and gas industry and since then, the favorable aspects which kept the tax increase from being even larger have been reversed.

(37) How much does ExxonMobil invest annually in new technologies?

A: ExxonMobil spends more than $1 billion on technology development annually.

(38) What effect did President Hugo Chavez's decree to nationalize your assets in Venezuela have on future investment/exploration plans abroad?

A: Unfortunately, current conditions and emerging challenges have led some to pursue isolationist or protectionist energy policies which could have severe consequences for the global economy and for global energy security over the longer term. The key to addressing global energy challenges lies in free markets and strong international partnerships, with the "rule of law" as an essential foundation. It continues to be very important that industry, policymakers and civic leaders work together to support these important principles.

In addition, ExxonMobil is confident that its ability to complement partnerships with National Oil Companies, and other partners, will assure its future competitiveness. In these partnerships, we are able to align interests to maximize the value of a given resource. We provide: (i) proprietary technologies and financial capability; (ii) proven operations and project management capabilities; and (iii) highly qualified and experienced professionals. With technology, we can overcome the challenges associated with geography and geology, i.e., much of the Earth's remaining recoverable oil resources are found in complex geologic formations, in remote locations, and under harsh conditions. With project execution excellence, we have demonstrated our ability to deliver on project completion timelines, consistent with integrated contracts, and within budgets. This capacity is critical in today's relatively high price environment, where inefficiencies and mistakes are easily magnified.

(39) On page four of your testimony, you state, "Government mandates and subsidies distort market forces and impede technological innovation." Can you give examples of unintended consequences of government mandates and subsidies regarding energy manners?

A: Examples of unintended consequences of government subsidies and mandates in energy markets include:

a) The 1970s crude oil and petroleum product price controls and allocation/ entitlement systems, which created shortages of petroleum products and long lines at gas pumps in the U.S., and which promoted construction of a large number of small "refineries" which produced little-to-no finished product but collected benefits under the entitlements program.

b) The 1980 Windfall Profits Tax, which reduced domestic crude oil production as much as 6 percent and increased imports as much as 16 percent, according to the 1990 report by the Congressional Research Service.

c) The 1980 creation of the U.S. Synfuels Corp, which spent over a billion dollars to create synthetic liquid hydrocarbons, creating a boom and bust leading to considerable economic hardship and no lasting gain.

d) The domestic ethanol tax credit and tariff, which promotes domestic corn-based ethanol over less expensive Brazilian sugarcane-based ethanol. Ethanol subsidies began in 1973 and resulted in only modest domestic capacity increase with no breakthrough technical innovation.

e) The recent Renewable Fuel Standards, which has spurred more significant increase in domestic corn ethanol capacity, raising concerns about the effect on human and animal food prices. While research has increased in the field of cellulosic ethanol production, breakthroughs to substantially reduce cost and increase scale remain elusive. Worldwide, biofuels mandates have raised concerns about deforestation, water use, and higher food prices.

f) The 1990 Clean Air Act Amendment mandate for at least 2 percent oxygen in reformulated gasoline, intended to promote ethanol use but which lead to increased use of MTBE, since insufficient ethanol capacity existed.

g) The proliferation of boutique transportation fuel requirements in the U.S, which reduces the flexibility of the petroleum supply system to respond to disturbances and which increases costs to consumers.

h) The California failed electricity market deregulation, where a combination of wholesale deregulation and retail price controls resulted in total system failure and bankruptcy of power supply utilities.

i) The California methanol mandate, which required investment in vehicles and fueling infrastructure for methanol to replace petroleum, but failed to stimulate a replacement industry.

j) The California Zero Emissions Vehicle mandate, which has forced significant investment by auto companies without generating the hoped-for breakthrough in battery or fuel cell technology.

k) The 1973 Alaska North Slope crude oil export ban, which reduced the value of ANS crude and the subsequent royalties and taxes collected until repeal in 1995.

l) Subsidies for fossil fuel use in numerous countries around the world today, including China, Indonesia, Mexico, India, Iran, and Venezuela, encouraging consumption and discouraging the development and pursuit of energy use efficiencies.

ExxonMobil is donating this week's op-ed space to the National Math and Science Initiative.

Do the math

A proven formula for improving U.S. math and science proficiency.

Imagine if we could dramatically increase the number of American high-school students taking — and passing — Advanced Placement exams in math and science.

Imagine the improved odds of success for these young people. Students who pass AP exams are three times more likely to earn a college degree than those who do not.

Imagine the benefit to our nation, where declining math and science proficiency poses an increasing threat to America's future as an innovator and economic leader.

NATIONAL MATH + SCIENCE INITIATIVE

No need to imagine any longer. It's already happening in 143 high schools in seven states.

These schools are implementing the Advanced Placement Training and Incentive Program supported by the National Math and Science Initiative (NMSI).

This innovative program offers training for AP teachers, tutoring for students, and mini-scholarships, and provides greater opportunities for minorities and economically disadvantaged students.

The results are startling: For participating schools in their first year of the program, AP enrollment in math, science, and English rose by nearly 60 percent this year alone. As a result, in 2009 the number of students taking these AP exams in these 143 schools is projected to be over 30,000.

NMSI's other flagship program, UTeach, which encourages math and science majors to pursue careers in teaching, had similar success. At the University of Texas and the 13 universities awarded grants to begin UTeach programs, over 1,000 students enrolled.

Think of it: In just one year, a thousand more bright minds committed to teaching math and science, and thousands better prepared to compete in today's technology-driven economy.

We can multiply that success — across schools, and across the nation. Many more states and universities stand ready to adopt NMSI's programs once funding is available.

In support of NMSI, ExxonMobil has committed the largest single financial gift ever for improving math and science education. Other funding partners include the Bill & Melinda Gates Foundation and the Michael & Susan Dell Foundation. We invite other private donors to join this important, urgent cause.

We also urge government to back this education movement. Congress recognized the urgency of improving math and science education by passing the America COMPETES Act earlier this year, but has not funded the programs.

Now, as lawmakers weigh how best to fund our nation's educational goals, NMSI's programs are available as proven, powerful tools that can be replicated across all 50 states.

Because when you do the math, one of the best ways to strengthen America's technological leadership is to invest in the students who will become tomorrow's innovators.

To learn more, visit www.nationalmathandscience.org.

SHELL OIL COMPANY RESPONSES TO POST-HEARING QUESTIONS (APRIL 1, 2008 HEARING)

THE SELECT COMMITTEE ON
ENERGY INDEPENDENCE AND GLOBAL WARMING

Select Committee on Energy Independence and Global Warming

1) How much did your company invest in renewable energy technologies by year and by project over the last 10 years?

   The investment for research and development is not broken out by business, but our total investment in our renewables business and technologies is well over a billion dollars in the past five years.

2) How much does your company plan on investing in renewable energy technologies by year in coming years?

   Driving down the cost of viable renewable technologies and positioning Shell for leadership in this high-growth sector is also an important part of investing with a long-term strategic view. The investment for renewable technologies is based on the needs of the business for procurement of turbines, towers, gearboxes, etc. in relation to wind projects or for biofuels and hydrogen, which infrastructure is needed and in line with the permitting that has been approved. The government can also play a positive role in supporting the demonstration phase of new technology, particularly advanced biofuels.

3) Based on the fundamentals of supply and demand, what does your company estimate the price of oil should be were it not for speculation, and other factors? Mr. Simon from ExxonMobil testified that their analysis of fundamental supply and demand suggests a price of oil in the $50-55 range, and prices above that figure are due to speculation, weakening dollar and geopolitical stability. Do you agree or disagree with that analysis?

   There are many factors affecting prices, not the least of which are growing world demand coupled with diminishing existing supplies and limited accessibility to new energy resources. It has been Shell's policy to not engage in public comments regarding energy price forecasts.

4) What percentage of the current price of oil is a result of speculation?

   While the number of speculative trading participants, including commercials users, such as Shell, and non-commercial users, such as pension funds, endowment funds and hedge funds, has increased, it is unclear what effect this activity has had on prices, if any. The Commodity Futures Trading Commission (CFTC) recently stated that there was an absence of evidence that speculation had driven up oil prices. What is clear, however, is that the combined oil commodities trading community is telling us that we need to produce more oil.

5) How much did your company invest last year in emerging energy technologies in North America and what types of technologies would that include?

   Shell is involved in many emerging technologies and participates in joint ventures on several fronts for biofuels, hydrogen, wind and solar. The government can also play a positive role in supporting the demonstration phase of new technology, particularly advanced biofuels.

6) In 2030, what percentage of global energy demand will be met by fossil fuels?

   Leading experts have calculated that by 2030, the world will demand an additional 35 million barrels of oil per day and 64 percent more natural gas than we are producing today. It has also been forecast that these fossil fuels will continue to meet more than 50 percent of the world's energy needs at that time.

7) Do you think that it is important as an energy security issue, to use more of the US reserves of oil and natural gas? What are the best policies to assure our energy independence?

   If domestic energy security is a priority, as we believe it should be, policymakers should embrace three equally-important policy objectives—first, increased conservation and energy efficiency; second, development and commercialization of new energy technologies; and third, the development of any domestic energy resources in an environmentally safe and responsible way. At a time when global energy demand is rising and energy prices are high, there is every reason to embrace these three complementary energy policies.

   In addition, regarding domestic oil and gas resources, the US has abundant supplies that are not available for development, because government policies place them off limits. The result—domestic production of oil and gas has fallen steadily for the last 35 years. In fact, oil production in this country peaked in the 1970s. In 2006, the U.S. imported 3.7 billion barrels of oil to meet domestic demand, which is more than seven times the amount imported in 1970. The United States is the only country in the world that restricts the use of its own energy resources while transferring trillions of dollars of wealth to other countries in order to import energy.

8) What percentage of your stock is own by pension plans and retirement accounts?

   Around 10% of total outstanding RDS shares are held by US pension funds.

9) Do you support the use of coal-to-liquids as an alternative to traditional petroleum? If not, why not? As a follow up, wouldn't the use of coal-to-liquids significantly increase our domestic supply of fuel?

   Yes, we support coal to liquids technology (CTL) and believe it has the potential to contribute to liquid hydrocarbon supply. As the CTL technology is in the very early stages of development, the potential contribution is uncertain at this time as the industry deals with such issues as costs and management of greenhouse gas (GHG) emissions. Shell is participating in two CTL studies in Australia and in China with the goal of better understanding how these issues can be best managed in a way to enhance the potential contribution of CTL.

10) How much bio-fuel and ethanol do you think realistically can be substituted for traditional petroleum?

The Energy Independence and Security Act of 2007 sets a new Renewable Fuel Standard (RFS) requirement for 21 billion gallons of advanced biofuels and 36 billion gallons of total renewable fuels by 2022. Included are requirements for 1 billion gallons of biodiesel and 16 billion gallons of cellulosic biofuels. The remaining 4 billion gallons of advanced biofuels may come from any source. In addition to the longer-term goals, EISA significantly increased the short-term renewable fuel requirements and schedule compared to the 2005 energy bill. Thus, short-term, due to infrastructure limitations on the transport and blending of ethanol into gasoline, the refining industry will likely struggle to meet the mandated levels. Another key limitation is that under current law, the legal limit for ethanol in gasoline is 10 percent by volume. To efficiently increase the use of ethanol, that limitation would have to be raised to higher percent volume of ethanol such as 12%, 15%, etc. Going beyond 10 volume percent ethanol in gasoline, however, requires EPA, state and local governments to make a series of decisions relating to fuel specifications and infrastructure and vehicle specifications to allow higher levels of ethanol.

Longer term, the Energy Information Administration (EIA) in its Annual Energy Report (AEO) 2008 predicts that "Ethanol use in the AEO2008 reference case, grows from 5.6 billion gallons in 2006 to 23.9 billion gallons in 2030-about 16 percent of total gasoline consumption by volume and about 65 percent more than in AEO2007. The RFS requirements for 15 billion gallons non-advanced renewable fuel, 4 billion gallons advanced biofuel, and 1 billion gallons biodiesel appear achievable, but there is great uncertainty over the volume of cellulosic biofuel that will be available by 2022, as today neither cellulosic ethanol nor biomass-to-liquids (BTL) are commercially available. The EIA also recognizes this in their AEO2008 saying, "Although the situation is very uncertain, the current state of the industry and EIA's present view of projected rates of technology development and market penetration of cellulosic biofuel technologies suggest that available quantities of cellulosic biofuels before 2022 will be insufficient to meet the new RFS targets for cellulosic biofuels, triggering both waivers and a modification of applicable volumes, as provided for in Section 211(o) of the Clean Air Act as amended by EISA2007."

11) Are you involved in developing production in Canada's oil sands or Western oil shale? Do you believe those alternatives will become more viable if the price of oil continues to rise?

Shell is actively involved in developing oil sands in Canada and has been conducting research on the western slope of Colorado for oil shale for the past 27 years. The price of oil is not as important as developing these resources in a sustainable way.

12) The American Jobs Creation Act provides a tax credit of up to $1.00 per gallon for the sale and use of "agri-biodiesel" -- biodiesel from virgin agricultural products. The credit is $0.50 per gallon for biodiesel from recycled grease. In addition, the law provides an excise tax credit for biodiesel blends (i.e., biodiesel and conventional diesel). Producers are eligible for one credit or the other, but not both. The Energy Policy Act of 2005 extends these credits through 2008. Do you support making these credits permanent? Do you support increasing these credits?

For 2007, Shell US companies claimed only $24K in federal agri-biodiesel credit in 2007. So, this does not appear to be a significant issue historically.

- From: A National Dialogue on Energy Security: The Shell Final Report:
- Point 5 (of 12 point "Solutions") "Move biofuels beyond corn. . . . We need to invest in the new infrastructure required to move, blend, and distribute the billions of gallons of fuel, and governments—federal and local—need to assist with timely permitting." Pg. 14.
- Finally, from "Shell's Policy on Tax Incentives (2006)":

"Shell supports a level playing field....Shell does not believe in supporting one business at the expense of another one of its businesses....Shell does not support legislation that gives competitors a competitive edge at its expense."

"Shell supports reasonable incentives in certain contexts, and will take into account the following factors in making this determination:
---New markets or new technology. Incentives may be warranted where there are new markets or new technology (e.g. CCS, SURE, IOGEN). However, such incentives must consider: Prices (in a high price environment, incentives should be phased out as a general rule); and Time (incentives should have a limited time, and should be reflective of normalization in the marketplace.
---Societal goals. Shell supports incentives that support societal goals, including national security and environmental protection (e.g. new green technologies).
--Economic development. Shell supports incentives for infrastructure siting/expansion designed to enhance the competitiveness of a community or attract investment."

13) Do you support suspending or reducing the number of "boutique fuel mixes" that each state mandates in order to reduce gas prices in the near future?

Yes. State boutique fuel requirements undermine the flexibility that Congress intended to establish in the federal renewable fuels program, which calls for a nationwide program that encourages the most economic use of renewable fuels for the benefit of consumers by not dictating where renewable fuels must be used and by allowing credit trading. State ethanol and bio-diesel boutique fuel requirements reduce the overall efficiency of the gasoline and diesel distribution system. In the event of a supply disruption, such as a refinery outage or a pipeline break, boutique fuel requirements hinder the distribution of fuels potentially leading to supply shortages and price volatility in boutique fuel markets.

Shell is one of the world's largest distributors of fuel containing bio-components. We are investing in the development of 2nd generation bio-components using sources that meet standards for sustainable development and societal performance such as cellulose ethanol from agricultural residues. We recognize the positive contribution that these fuels can make towards the diversity of energy supplies, energy security and environmental goals. We support an open, fair and competitive global marketplace.

14) Do you believe that the Energy Independence and Security Act of 2007 went far enough to access US oil and natural gas resources?

In 2006, Congress took a significant step in opening some new oil and gas prospects in the Gulf of Mexico to exploration and development while, at the same time, providing those energy-producing states and local coastal communities in the region with a revenue stream to help ensure economic and environmental stability. Congress should extend Outer Continental Shelf revenue sharing for all coastal areas adjacent to offshore development and should make more areas available for offshore leasing.

We need more than oil and gas to meet demand. We need all forms of energy - plus conservation and energy efficiency. Shell commends Congress for passing the Energy Independence and Security Act of 2007 with more stringent CAFE standards. These standards and the other provisions in EISA will do more to increase energy efficiency than any other piece of legislation in recent memory. Congress should continue to adopt policies that encourage conservation, and companies like ours must continue to think more creatively about products and services we can develop to help customers use less energy. Consumers—and that means all of us—must think more about our own energy footprints: when and how we drive, what we buy, how we work and the kind of world we want to create for coming generations.

Government agencies must also have the staff and the resources needed to do the environmental analyses and other scientific studies that must underpin energy projects of all kinds. This data is critical and must be completed in a thorough and timely manner. Therefore, Congress should consistently authorize and appropriate funding for these key federal agencies to hire, retain or contract the expertise needed.

Shell supports the adoption of a federal law to reduce greenhouse gases. Specifically, we support a cap-and-trade program coupled with sector approaches. Such a program must include policies that lead to commercialization of a carbon capture and storage (CCS) technology. Congress should ensure that we address CO2 emissions as we make the transition away from fossil fuels to new energy sources.

Finally, we need individuals skilled in math, science, technology and engineering to build the workforce of the future that will bring new energy sources to America. School curricula should include more study of energy - where it comes from, how it is used and the impact of the energy choices we make. And these lessons should begin at an early age, to shape consumer behavior and encourage curious young minds to become our next generation of energy engineers. We welcome Congressional initiatives that will help secure a future energy workforce.

15) Are you actively pursing carbon sequestration and Enhanced Oil Recovery in your oil fields and has that work been successful? What more needs to be done in this area?

Shell has a strong legacy across the range of thermal, gas and chemical EOR processes, and is working hard to implement a clear strategy, growing the amount of EOR projects and implementing the different EOR technologies. Though we do not currently have any active CO2 EOR operations Shell was instrumental in developing many of the existing EOR field in the West Texas Permean Basin where CO2 is still being used successfully in recovery operations. In addition, Shell believes the role of pure Carbon Capture and Storage (CCS) will become increasingly important as countries develop regulations to meet CO2 reduction. We therefore support the development of CCS technology and are at the forefront of efforts to create an enabling framework for its widespread commercial deployment. To this end, Shell is aggressively pursuing both EOR and pure carbon capture and sequestration (CCS) opportunities around the world.

When EOR can be coupled with available man-made CO2, it is a "win-win" situation that can reduce the net funding required to create CCS infrastructure. EOR plays and will continue to play a prominent role in bringing a significant percentage of future reserves to the market. The existing regulatory and market mechanisms governing EOR are adequate and uniformly accepted by industry. This EOR experience and technology must be leveraged and applied to pure CCS development in order to make commercial scale deployment of CCS a reality.

Shell is pursuing stand-alone carbon capture and sequestration (CCS) projects and strongly believes that such projects will play a critical role in reducing CO2 emissions in an emerging carbon constrained world. A few examples of CCS projects that are currently being evaluated and some of their characteristics are listed below:

- Barendrecht in The Netherlands: Pernis Refinery producing apprx 1 mil tones of CO2 per annum.
  - CO_2 Management:
    - Summer: up to 380.000 ton CO2 to greenhouses
    - 150.000 ton CO2 to industry (e.g. carbonated drinks)
    - Planned
    - Storage 400.000 ton CO2 per annum in Barendrecht gasfields

- ZeroGen: IOGCC (Advanced Coal Gasification) Plant in Australia:
  - Project Characteristics:
    - Costs
    - Sharing of Cost by Both Public and Private Stakeholders
    - Creative Cost Reduction Techniques by Industry

All elements of CCS technology—CO2 capture from anthropogenic sources, CO2 transportation, CO2 storage and CO2 monitoring—exist today. All elements have been commercially deployed in various industries, specifically oil and gas production. In order to advance CCS, these technology elements must be integrated into large-scale CCS projects.

The primary barrier to large-scale integrated CCS projects is cost. It is our thinking that as a significant number of projects (recent IEA report states around 200 million tons stored) are put into operation, the costs begin to come down. Other broad barriers include the current weak carbon price signal; the lack of a clear regulatory regime; and public education and acceptance.

Specific recommendations for policymakers to consider adopting include:

- Incentives. Incentives should be provided to all types of CCS projects, and not restricted to CCS projects associated with capture from power plants. This approach recognizes that some high CO2 facilities have easily captured CO2 streams and therefore, might be the early movers. Incentives that are open to all allow for the greatest number of potential CCS projects to be built, increases the potential for technology breakthroughs, and potentially reduces the cost of projects on a faster timeline.
- Infrastructure for CCS pipelines. The existing regulatory regimes covering CO2 pipelines is largely workable. The challenge will be to ensure that the necessary scale of the new infrastructure needed is permitted and built. Governments can play a key role in this process.
- Permitting Requirements: EPA is developing regulations for permitting CCS projects under the Safe Drinking Water Act. There are other permitting issues that need resolution, such as the interface with other statutory requirements.
- Responsibility Issues: Project developers need clarity about operational responsibility issues, particularly as they relate to site closure, in order to properly assess critical aspects of CCS project designs.
- Education: The level of knowledge pertaining to the technical aspects and benefits of CCS is extremely low among most members of the general public. Governments can play an important role in building this knowledge and acceptance.

16) What is a ballpark figure of how much your company pays in taxes each year?

The following information is from "Delivery and Growth", RDS plc Financial and Operational Information 2003-2007, page 18.]

RDS taxes shown in the consolidated statements (IFRS) for the years 2005-2007:

	$MM
2005	$17,999
2006	$18,317
2007	$18,650

17) A couple of you mentioned the National Petroleum Council repot "Facing the Hard Truths about Energy" do any of you disagree with the findings of that report?

We support the findings of the NPC report.

18) Several of you mentioned the increasing cost of materials, difficulty in finding labor and specifically difficulty in finding engineers and scientists in oil and gas development. What policies do you think would help get the materials and people that you need?

Clearly our industry relies heavily on a sustained supply of technical talent. This is true not just at the professional level but also in respect of the operators and crafts at refineries/chemical plants and in our offshore operations. With that in mind policies that support and advance maths and sciences education through the primary and secondary school and, subsequently at the college and university level will clearly help. This could be in the form of an increased focus on training of school teachers in these areas, continued support through the National Science Foundation for the work of the Center for the Advancement of Process Technology and the provision of additional scholarships for technical disciplines at the college level.

19) Is there something in the manufacturing sector that we need to do to help insure that you get the supplies that you need?

Shell is committed to providing affordable, reliable energy to consumers; protecting the environment; creating jobs; and providing a strong return to our investors, which includes millions of Americans. The most pressing issue for our reinvestment in capital and thus in part in manufactured goods is that some of the tax increases proposed in the House and Senate will hinder these efforts. Many of the proposals currently being considered will leave the industry with less capital to make the investments necessary to meet America's growing energy needs.

These proposals would also damage Shell's ability to compete internationally with foreign government-owned oil companies. It is vital to America's energy security that we remain competitive in a world where 90 percent of the proven oil reserves are in the hands of oil companies controlled by foreign governments. These tax proposals will also impact our development of renewable energies—investments in production and goods and services in the wind, solar, hydrogen and biofuels manufacturing sectors. At Shell, profits from our fossil fuel businesses fund our renewable energy endeavors.

We are particularly concerned about the resurgence of a failed windfall profits tax policy intended to punish the oil and gas industry for its strong revenues. Our profits are re-invested in these new energy projects that will produce tomorrow's energy supply. We saw what such a tax did in the 1970s to discourage the development of new energy projects in the United States. It would not be wise to reinstitute a windfall profits tax, which history has proven discourages the development of new energy projects. Such new energy projects are needed to increase supply and help stabilize price in light of increased global demand and rising energy prices.

20) The International Energy Agency estimates that $22 trillion – in new energy investments will be needed by 2030. Where would that money come from?

Our understanding is that the IEA is basing this number on the amount of new infrastructure that will have to compensate for growing demand worldwide.

21) What would be required to get biofuels to a commercial scale that they could replace oil in the United States?

We are seeing a step-change in the growth of demand for energy, particularly as emerging economies, such as China and India, enter into more energy-intensive phases in their economic development. It will be vital to become more efficient in how we use energy, how we develop oil and gas resources and how we expand the use of alternative sources of energy such as biofuels—we will need all of the energy we can get. Alternative and renewable energy sources will play a role and grow substantially. Energy efficiencies will improve as new technologies are developed and implemented. But leading experts forecast that oil and natural gas will continue to meet more than half of the world's energy needs in 2030.

The Energy Independence and Security Act of 2007 CAFE standards, new RFS and the other provisions will do a lot to move us towards diversifying and expanding our energy portfolio. Congress should continue to adopt policies that encourage conservation, and companies like ours must continue to think more creatively about products and services we can develop to help customers use less energy. Consumers must think more about our own energy footprints: when and how we drive, what we buy, how we work and the kind of world we want to create for coming generations. Government agencies must have the staff and the resources needed to do the environmental analyses and other scientific studies that must underpin energy projects of all kinds. And we need individuals skilled in math, science, technology and engineering to build the workforce of the future. School curricula should include more study of energy – where it comes from, how it is used and the impact of the energy choices we make. And these lessons should begin at an early age, to shape consumer behavior and encourage the next generation of energy engineers.

22) In your testimony, several of you point to speculation as a contributing cause of high crude oil prices. I have introduced legislation, the Prevent Unfair Manipulation of Prices (PUMP) Act (HR 594), which would improve oversight of "dark markets" which are currently unregulated by the Commodity Futures Trading Commission. In our December 2007 Oversight and Investigation Subcommittee hearing, we heard testimony that this could reduce the cost of oil by $30 a barrel. Do you believe that speculation in the market is driving up the price of oil? Would you support this legislation?

Exchanges like the Intercontinental Exchange (ICE) provide the ability to trade both physical and financial products that are not traded elsewhere. For example, no other exchange provides liquid markets for forward sales of wholesale power. ICE provides another way of doing business in addition to direct bilateral sales and transaction arranged through brokers. There are differing views as to the influence, if any, that oil futures and options investments have on the price of crude oil. If Congress decides the commodity markets need more regulation than currently exists through market rules, guidelines and penalty systems as prescribed by the CFTC, then Shell will, as we do in all areas of our businesses, ensure that we comply with any and all regulations imposed.

23) What is the average number of barrels of oil your companies trade each day on NYMEX? On the InterContinental Exchange?

Trading volumes fluctuate based on a variety of reasons including weather, geopolitical events, and supply and demand. In recent years, while the exchange volumes have increased significantly but Shell companies' volumes remain a very small component in the market. This considerable market growth has actually increased the number of traders in the market and, thereby, has increased liquidity leading, we believe, to a greater level of transparency in the price discovery process.

24) During the April 1, 2008 hearing, you each spent most of your time complaining about taxes, specifically that the Renewable Energy and Energy Conservation Tax Act (H.R. 5351) passed by the House would repeal $18 billion over ten years in subsidies to your companies. Several times during the hearing, you also said that your companies do not support mandates and subsidies for renewable fuels. Over the next ten years, your companies are expected to make $14.6 trillion. H.R. 5351 would only account for approximately one tenth of one percent of your gross income! How can you insist on retaining these subsidies and tax breaks for your companies while opposing assistance for renewable energy?

HR 5351 repeals the section 199 deductions for large integrated oil and gas companies, and negatively changes the determination of FORI and FOGEI for foreign tax credit purposes, which could lead to double taxation of foreign profits.

We do not believe that it is appropriate to tax selected oil companies for a number of reasons. Oil is a commodity, and the marketplace sets prices. Crude oil and natural gas prices fluctuate substantially and unpredictably. The industry must manage its business in the face of these severe price fluctuations. The business requires massive investment over long periods of time—even when prices are relatively low—to ensure that there will be energy supplies in the future.

Many of the tax proposals currently being considered will leave the industry with less capital to make the investments necessary to meet America's growing energy needs. These proposals would also damage Shell's ability to compete internationally with foreign-government owned oil companies. It is vital to America's energy security that we remain competitive in a world where 90 percent of the proven oil reserves are in the hands of oil companies controlled by foreign governments. Finally, these tax proposals could impact our development of renewable energies. Some members of Congress propose increasing taxes on the very oil and gas companies that produce the renewable energies the public wants more of. At Shell, profits from our fossil fuel business fund our renewable energy endeavors.

At a time when we need energy companies to continue the record level of investment in developing our energy resources, it is unfortunate that some in Congress are pursuing tax policies that will discourage this needed investment. These policies include proposals such as the repeal of the domestic manufacturing deduction for select US oil and gas companies, which would reduce domestic oil and gas production and negatively affect our nation's energy security. Energy companies invest significant amounts in new technologies, new production, refining and product distribution infrastructure and environmental improvements, and make such expenditures considering long-term commitments. Continued and sustained capital expenditures are required each year to find and develop energy resources, despite the cyclical nature of the business and risks involved. Given the industry's long-term capital allocation models in a global and free marketplace, it is important to have stable and consistent tax policy in order to meet all of the challenges ahead.

25) At the American Society of Newspaper Editors Convention on April 14, 2005, the President said, "I will tell you, with $55 [a barrel] oil we don't need incentives to oil and gas companies to explore. There are plenty of incentives. What we need is to put a strategy in place that will help this country over time become less dependent. It's really important. It's an important part of our economic security, and it's an important part of our national security." Today, crude oil prices are double the President's example! Do you agree with President Bush that oil and gas companies do not need incentives to explore when oil is more than $55 a barrel? Do you agree with President Bush that we should instead be investing in renewable energy that will help this country become less dependent on oil?

Shell believes that the free market system will provide the necessary impetus for its businesses, without recourse to government support. Shell also supports reasonable incentives in cases where there are new markets/new technologies; where incentives support societal goals; or where incentives are given to enhance competitiveness or attract investment.

From time to time the Congress has passed a number of federal tax incentives to encourage domestic production of energy. A good example of this is HR 6, the Energy Policy Act of 2005 (PL 109-58). Among other things, PL 109-58 contains various incentives designed to encourage domestic production of oil and gas and renewable fuels, and to increase domestic refining capacity. In many cases, significant capital investment is required for energy projects with no return for many years. For example, in the OCS, it could take 10 years from the time a property is leased to initial production. Significant additional time is needed to recoup the capital invested. And such a facility could cost over $1 billion. Consequently, Shell supports and relies upon stable regulatory and fiscal policies that enable companies to develop energy projects and secure energy supplies. Furthermore, Shell supports reasonable incentives Congress deems in the national interest to encourage domestic production. In this regard, Shell supported PL 109-58, overwhelmingly approved by the Congress, which contains incentives for fossil and renewable fuels. Such incentives can help augment US security and promote emerging technologies.

26) I have attached internal memos from Chevron, Texaco, and Mobil. The Chevron memo quotes a "senior energy analyst at the recent API convention," stating "if the US petroleum industry doesn't reduce its refining capacity it will never see any substantial

increase" in profits. The Texaco memo complains that "supply significantly exceeds demand" leading to "very poor refinery margins and very poor refinery financial results." The Mobil memo advocates keeping a smaller refiner, Powerine, from reopening, stating that a "full court press is warranted in this case." From 1995 to 2002, more than 30 refineries have been closed in the United States. Have any of your companies applied for permits to build new refineries? If yes, how long did it take to obtain the necessary permits? In July 2007, gas prices increased 30 cents overnight in Escanaba, Michigan. There were no supply disruptions or other major events that would influence the price this significantly. Is there any logical explanation why prices would increase 30 cents in that short of time? On May 23, 2007, the U.S. House of Representatives passed H.R. 1252, the Federal Energy Price Gouging Prevention Act by an overwhelming vote of 284 to 141. Please explain why this legislation is not needed, given the significant price increases consumers continue to face.

Shell does not condone price gouging and we encourage dealers and jobbers to price responsibly, and virtually all have done just that. Shell and our operators strive to be competitive and have a history of being sensitive to price changes, especially when caused by significant disruptive events. The referenced legislation, on the other hand, would not benefit consumers but instead lead to an exacerbation of supply needs for the effected areas. The bill subjects honest, good faith product sellers and distributors to criminal and onerous civil liability under vague standards for market actions or events occurring anywhere in the world. Rather than accomplish its avowed purpose, the bill would harm consumers by skewing normal market forces artificially, resulting in more severe and extended shortages of products, and ultimately higher prices. This conclusion arises from the fundamental premise that gasoline prices are set by the marketplace according to the economics of supply and demand. Numerous investigations of the industry over the past thirty years have found that no anticompetitive manipulation has occurred and that market participants are consistently found to have reacted to market conditions, as one would expect firms to behave in a competitive market.

Regarding refinery expansions, Shell has invested over the years to increase our refining capacity. We also recently announced that our joint venture, Motiva, is spending around $7 billion to double the capacity of its refinery in Port Arthur, Texas. This project, when finished in 2010, will be one of the largest refineries in the United States and in the world. By adding 325,000 barrels-per-day capacity, the expansion is equivalent to building a new refinery.

27) In May 2004, the U.S. General Accounting Office released its report, "Effects of Mergers and Market Concentration in the U.S. Petroleum Industry." In this report, GAO found that over 2,600 mergers have occurred in the U.S. petroleum industry since 1990. The GAO also pointed to economic literature that suggests that firms sometimes merged to

enhance their ability to control prices. Each of your companies today is the result of significant mergers in the industry. Do you see any more mergers taking place?

The Federal Trade Commission (FTC) has been quite rigorous in its review of industry mergers. In Shell's case, the FTC has required a number of divestitures that were designed to prevent declines in the numbers of competitors or increases in concentration. According to a 2006 FTC investigation, no U.S. refiner holds a substantial capacity share either nationally or regionally. Likewise, a 2004 FTC study found that, "[d]espite increases in concentration at some production levels over [the last two decades], particularly since the mid-1990s, most sectors of the petroleum industry at the national, regional, or state level generally remain unconcentrated or moderately concentrated". Shell does not comment publicly regarding future transactions.

28) In your testimony, almost all of you mention "more domestic drilling" as your top solution to high-energy prices. What assurance can you provide that oil and gas from the Arctic National Wildlife Refuge (ANWR), the Outer Continental Shelf (OCS), or other domestic sources would stay in the United States? What is your response to economists that tell us that the oil and gas will likely go to higher priced markets in Japan and elsewhere?

Currently, 100 percent of oil produced in Alaska goes to domestic refineries and 100 percent of GOM production goes to US refineries. Historically some North Slope oil has been shipped to Asian markets but it has been a rare occurrence The US is the largest market for crude oil and production from sources close to market are better positioned to service those markets.

29) In May 2006, the Energy and Commerce Committee held a hearing on gas prices, and we discussed the crack spread, or the difference between a barrel of crude oil and the refined product. At this hearing, the average crack spread for a refinery in 2006 was estimated to be about $20 to $30 a barrel by Howard Gruenspect, the Deputy Administrator at the Energy Information Administration. Mr. Gruenspect testified that a crack spread of $8 or $9 is sufficient to cover refining expenses and provide a reasonable profit to the facility. What is your current crack spread at the refineries your companies operate? Why have your companies scaled back their refinery expansion plans to keep crack spreads high?

Shell has invested over the years to increase our refining capacity. We recently announced that our joint venture, Motiva, is spending around $7 billion to double the capacity of its refinery in Port Arthur, Texas. This project, when finished in 2010, will be one of the largest refineries in the United States and in the world. By adding 325,000 barrels-per-day capacity, the expansion is equivalent to building a new refinery.

30) Please provide a list of oil and gas leases currently in the possession of your company and its subsidiaries, and give a status report as to the state of the production of each of these leases.

Attached is a spreadsheet that lists our current federal leases both onshore and offshore and reflecting the location and status of these leases. The net acres column represents Shell's equity interest in the leases. State codes are self explanatory except FG= Federal Gulf and FA= Federal Alaska. The first tab includes all the data, and there are subsequent tabs with the data broken out by Alaska, Gulf of Mexico, and Onshore.

Shell has acquired a large number of OCS leases in recent lease sales and many of these leases are in very early stages of evaluation. Many leases that are labeled as "non-producing" are leases that are new and are yet to be explored or drilled or are near an area that is currently being explored or developed. Until a lease is explored by drilling, there is no way of knowing whether there are any accumulations of hydrocarbons located on a lease. Since it takes many years to explore, develop and place leases on production and since production does not begin all at once on any area of leased acreage (it occurs in phases), there will naturally be non-producing blocks for a significant period of time. Other leases that are "non-producing" have legal or regulatory actions underway that are preventing their exploration and development. For instance, one of the obstacles preventing exploration of certain Alaska leases is litigation in which the MMS' approval of Shell's "Beaufort Sea Outer Continental Shelf Lease Exploration Plan 2007- 2009" is being challenged.

After an exploratory well is drilled and testing is conducted (which usually requires additional appraisal wells) to determine the extent of the discovery, a company will need to decide if further development is economically feasible. When a company fails to find commercially economic accumulations, the company will either relinquish the lease(s), allow the lease(s) to expire, or seek knew technologies that allow the reserves to be developed economically.

Failure to conduct operations on a lease within its primary term will result in the termination of the lease and loss of all capital invested in that lease. These expired leases are made available again for future lease sales.

31) As fuel prices rose over the past 6 years, has American demand decreased? Why or why not has this occurred? If gas taxes were increased, do you think demand would decrease?

Did this happen in European countries when then imposed large gas taxes?

According to the BP Statistical Review of World energy, US oil demand has increased by an average of 0.9% per year between 2002 and 2007. This is somewhat slower than growth in the previous five years of 1.2% per year, on average. Over the same period, from 2002 to 2007, oil demand in Europe rose by 0.1% per year, on average. However, changes in the overall level of oil demand depend on many other factors apart from price or taxation levels, including income growth, the availability and affordability of alternative fuels, the composition of the vehicle fleet, home heating boiler installations and industrial equipment, such that demand does not adjust only to price levels or price changes. Oil product taxation policies have been in place in Europe for many years, operating in a variety of market conditions and economic environments, such that, again, we cannot draw a direct relationship between taxation levels and demand trends.

32) At current projections, when will your current reserves be depleted?

We are not in a static situation. We are continuously producing new fields and are assessing new prospects in North America and around the world. We fully expect to continue producing oil and gas for many years into the future.

33) When do you expect underdeveloped countries will reach a level to where they will begin to significantly buy oil for use? How will this affect supply and fuel prices?

Already we are seeing material volumes of oil consumed by developing countries, with the lion's share of oil demand growth coming from China, India and the Middle East. But this is only the start. Today, total non-OECD demand is around 75 percent of OECD demand for oil, and it could match OECD demand by around 2013, growing to approximately one-and-a-half times OECD demand by the mid 2020s. We expect non-OECD demand to continue growing and OECD countries to look to curtail growth in oil and go for efficiency and alternatives, as well as embracing clean coal technology. China, where domestic production is in decline, could be importing roughly three-quarters of its oil needs by 2030. While natural gas use is still in its infancy in both China and India, both countries have now firmly entered the market for Liquefied Natural Gas, with China concluding several long-term supply contracts in 2007.

The impact of this rising demand for oil and natural gas on the world's ability to increase hydrocarbon supplies is likely to remain limited, because political limitations on access and cost inflation currently determine the industry's ability to invest in new projects. For example, here in North America, potentially large hydrocarbon resources remain off-limits to the industry.

34) If all conventional, alternative, and unconventional sources of oil in the U.S. were to be developed, how long would the supply last based on current estimates of increased usage?

Looking at crude oil alone, it is estimated that world conventional oil resources are about 1 trillion barrels of oil equivalent. Of which the US market holds 50 billion barrels. Adding in US unconventional crude alone takes the US number to 1 trillion. This is the equivalent of the world resources available today. This doesn't account for the natural gas market or alternative sources that are not yet commercial. If this is added, the number increases even more.

35) Please describe to this committee your short, middle, and long-term plans for oil and renewable energy development.

Shell wants to help provide abundant, affordable energy as far into the future as we can imagine. We consider abundant, affordable energy a cornerstone of America's energy security. But we recognize that achieving this goal will require aggressive short-term, medium-term and long-term plans.

Short term:
First, Shell would like to outline the short-term U.S. energy needs and the steps Shell recommends for the next decade. In the short term, the United States will remain a fossil-fuel-based economy because, very simply, we cannot attain the commercial scale and infrastructure needed to meet energy needs through alternative energies. We won't have the pipeline system to pump ethanol. We won't have the transmission lines to bring hundreds of gigawatts of wind from remote windy plains and mountains to cities. That kind of scale and infrastructure won't be available for decades to come. Largely for this reason, the International Energy Agency estimates that under a "business-as-usual" scenario, alternative energy will account for only 8 percent of U.S. energy use in five years.

In the short term then, we need more oil and gas now to meet growing demand. We can meet that demand in two primary ways. First, we can responsibly develop the more than 100 billion barrels of technically recoverable oil and gas in this country that are currently off limits to development due to federal policy. Unless we intend to increase our reliance on foreign oil, we must have increased access to America's own energy resources both onshore and on the Outer Continental Shelf. Shell is committed to developing any resources in an environmentally sound and responsible manner.

Second, we can increase the supply of natural gas to our country by using liquefied natural gas technology that allows us to store and ship gas safely in a liquid state. As a nation, we must put aside our resistance to building the infrastructure necessary to receive LNG, especially on the East and West Coasts.

In addition to these two important avenues, we must continue researching environmentally sensitive and commercially feasible ways of developing unconventional oil and gas resources, including the trillion barrels of oil that remain trapped in shale in Colorado, Wyoming and Utah.

Medium term:
Shell anticipates that in the medium term – between the next 10 to 25 years – oil and gas will remain the primary energy sources, but biofuels and wind will play greater roles in meeting energy demands.

Shell is one of the world's largest distributors of biofuels and one of the first companies to invest in second-generation biofuels that use cellulosic materials that do not compete with food crops.

However, we are very concerned about the provisions of the Energy Independence and Security Act of 2007 that mandate a more than five-fold increase in the amount of alternative fuels, such as ethanol, from 7.5 billion gallons a year in 2012 to 36 billion gallons a year in 2022 to the nation's energy supply.

Wind offers another solution to carbon dioxide emission challenges and to increasing our energy diversity. In this country, Shell WindEnergy now has interest in or operates eight wind farms in six states. Wind technology, however, is often limited by lack of transmission systems to move the wind energy from remote hills and potential offshore wind farms to connect with the electric grid. We need sound federal and state policies that support new transmission systems to enable this technology to be adopted more widely.

Also during the medium term, Shell believes that our nation must move to clean coal technology – using our most abundant natural resource to generate electricity in a way that allows us to manage carbon dioxide emissions. However, the introduction of this technology is hampered by the need for large, upfront capital investments. Public policy is needed to create the enablers to stimulate the production of clean coal technology and associated carbon capture and storage.

Long term:
Over the long term, spanning 25 years and beyond, Shell anticipates that the U.S. economy will continue to depend on oil and gas with an ever-growing contribution from alternative fuels. We will see a strong growth of the clean fuels mentioned in the medium term, but we will, in the long term, see more alternative fuels that are in their infancy now become commercially viable components of the overall energy mix. Hydrogen is an example.

Hydrogen is the world's most plentiful element and is part of the Shell portfolio of future low-carbon fuels. As a fuel, hydrogen offers the potential to substantially reduce emissions, reduce our reliance on fossil fuels and increase America's energy security. There are obstacles to be overcome, but we think hydrogen could become a commercially viable transport fuel in the coming years. Shell is developing hydrogen supply chains, which, in the longer term, may rely increasingly on renewable sources of energy. We partner with car manufacturers and local and national governments to coordinate the construction of hydrogen fueling stations in areas where fuel cell vehicles are being introduced. In the United States, those include the Los Angeles and New York City metro areas. Since 2004, Shell has operated an integrated gasoline/hydrogen station in Washington, D.C., not far from Capitol Hill. Last year, we opened a hydrogen station in White Plains, New York, and plan to open our first hydrogen station in Los Angeles this spring. It will probably take a couple of decades to make hydrogen a commercially available option. However, for our grandchildren's children, it may become the standard fuel of choice.

Clearly, Shell believes that alternative energies will play an increasing role in the energy mix. We are planning for it. We invest a significant portion of our profits into developing energy technologies. We believe our commitment to technology and innovation distinguishes us from many of our competitors.

But we must approach our energy challenges realistically. Because of the extensive lead-time and financial commitment required to bring new technologies to market, fossil fuels will remain at the core of global economies for the foreseeable future. Shell does not see that as an "either-or" proposition. It is a "both-and" proposition. The balance between conventionals and alternatives will be established by what is possible in the future. We will need all of these energy sources, and others, to fuel the world.

As a nation, we face tough choices to balance our energy needs, our economic well-being, our quality of life and our respect for the environment. At Shell, we are firmly committed to bringing energy security to America.

36) On Page 4 of your testimony, you use the term "resource nationalism." Is the United States alone in this new position toward oil and gas exploration? Do we actually have policies in place that help develop our US resources?

The US has abundant supplies that are not available for development, because government policies place them off limits. The result—domestic production of oil and gas production has fallen steadily for the last 35 years. In fact, oil production in this country peaked in the 1970s. In 2006, the U.S. imported 3.7 billion barrels of oil to meet domestic demand, which is more than seven times the amount imported in 1970. The United States is the only country in the world that restricts the use of its own energy resources while transferring trillions of dollars of wealth to other countries in order to import energy."

37) Shell is heavily involved in gasification and gas-to-liquids fuel. What do you think the most promising technologies are in this area?

Gasification and gas-to-liquids (GTL) are complementary technologies (the GTL process includes a gasification stage whereby natural gas is processed into what is called syngas—an ultra-clean tar-free synthesis gas). Regarding coal gasification, this is one of the cleanest methods for harnessing coal's energy potential. We developed our proprietary technology in 1972 with a small pilot plant in Amsterdam.

Today, a growing number of countries use Shell's technology to operate commercially viable coal gasification plants. Shell's leading-edge coal gasification technology provides extensive benefits to its users, including lower life cycle costs and a lower impact on the environment than competing technologies. Our technology could also be used in the conversion of coal to liquids, which would provide a valuable source of transport fuels. CTL studies, however, are in their very early stages.

GTL technology converts natural gas into a range of high-quality products that are normally derived from crude oil, such as transport fuels, naphtha and base oils for lubricants. GTL fuel is a cost-effective alternative fuel that can diversify energy feedstock sources, reduce local emissions and encourage sustainable mobility. In 1973 we developed a proprietary GTL process called Shell Middle Distillate Synthesis.

We have developed unparalleled operating and marketing experience in GTL through the world's first commercial low temperature GTL plant in Malaysia, which started-up in 1993. Today, Shell is leveraging this technology and experience to support the development of the world-scale Pearl GTL project in Qatar.

38) How does your experience pursuing Liquefied Natural Gas (LNG) in the United States compare to the experience of pursing such projects in the other countries where you have projects under construction?

Development of LNG regasification terminals that would provide US energy consumers the ability to access new, much needed supplies of natural gas from around the world and diversify our nation's energy mix, is extraordinarily more difficult and time consuming than what Shell has experienced elsewhere in the world. As an example, Shell and TransCanada Pipeline Company are jointly developing a new regas terminal named "Broadwater Energy" to be located near the middle of Long Island Sound, 9 miles offshore from New York and 11 miles offshore from Connecticut that would serve the natural gas starved New York metropolitan regional market. This region pays the highest energy prices in the country and has enormous challenges meeting clean air requirements due to its continued use of older, dirtier pulverized coal and fuel oil power generation and desperately needs plentiful, affordable new supplies of natural gas. Yet, in the time that it has taken the Broadwater project to undertake the preliminary development and regulatory review process, Shell has developed, built, and placed into service three new regas terminals in other parts of the world. This is even in light of newly enacted legislation that was designed to streamline the regulatory review process to approve the siting, construction, and operation of these much needed LNG terminals. The protracted, contentious process of building new energy infrastructure in the US is resulting not only in undue delays in developing LNG terminals, but more importantly, drives up the cost of new facilities and delays the delivery of this much needed natural gas to US consumers resulting in needlessly increasing the cost of energy for the US.

39) On Page 7 of your testimony, you note that in 2005, you estimated that the average cost for a deepwater oil rig rental was approximately $200,000 a day – and in 2007 the average daily costs for a deepwater exploration well was $759,000. It sounds to me like you aren't necessarily comparing apples to apples. Could you clarify those numbers for me?

The two columns below show the average cost for exploration wells and development wells from 2002 through 2007. The numbers are based on cost data from the Dodson database, the largest cross business database for wells drilled in the Gulf of Mexico. These numbers are a more simplistic indicator of the increase in exploration and development costs.

Exploration Wells:
2002: $390M/d
2003: $407M/d
2004: $409M/d
2005: $451M/d
2006: $720M/d
2007: $759M/d

Development Wells:
2002: $301M/d
2003: $328M/d
2004: $515M/d
2005: $428M/d
2006: $693M/d
2007: $729M/d

Overall, based on the above industry data, the GOM Deepwater well cost on average has gone up about 70% over the last 3 years.

40) As for the projects where Shell is pursuing wind energy, what has been your experience with consistency of available power generation?

Wind energy is fundamentally an intermittent source of power. Shell is looking at different ways of making the power source more consistent by experimenting with pump-hydropower or compressed air storage, but those technologies would not offset base load power at this time.

41) Is the demand for petrochemical products also on the rise? And is that contributing to the rising cost of gasoline?

Petrochemical feedstocks account for approximately 2.5% of US refinery yields, so they have only a small impact on the availability of refined products such as gasoline. Although global demand for petrochemicals is expected to increase in line with world economic growth, demand and capacity increases are primarily in the Middle East and Asia Pacific regions rather than the US. As a result, changing demand for petrochemical feedstocks is only a small factor affecting the availability of gasoline in the US.

42) You specifically mention the potential for oil shale development in the western United States. What do you think would need to happen to make projects a reality in Colorado, Wyoming and Utah?

Shell needs timely publication of final regulations in order to provide a reliable framework for making future commercialization decisions. Federal oil shale regulations are needed many years in advance of a move towards a commercial decision. We need time to finalize project design, get all necessary permits, construct the project, operate it to see how it performs, analyze the results, submit an economic and environmental analysis to BLM, and undertake reclamation. We certainly need commercial leases sometime in the middle part next decade but need BLM to finalize oil shale regulations many years in advance of actual preference right lease issuance. In other words, we must understand the rules of the road in some fashion in order to consider our research efforts further. To illustrate the point, imagine a pharmaceutical company deciding whether to spend huge amounts of research and development dollars for a new cancer cure when the company knows in advance that there is no method by which the drug can be taken to market. The pharmaceutical company would obviously not make the investment, and so it is with oil shale development. We are trying to climb a technology hill that no one has ever been able to climb before. The Congress has now made that climb more difficult by putting a regulatory blindfold on us. If regulations are not issued soon, we may never be able to reach the top of this steep technology hill.

43) On Page 9 of your testimony you note that government agencies must have the "staff and resources needed to do the environmental analysis and other scientific studies that

must underpin energy projects of all kinds." Do you mean just the federal government or state governments as well? Where do you suggest the best federal staffing investments would be?

With respect to Federal leases both onshore and offshore, we believe that it is imperative that the Congress provide adequate funding and staffing to the Department of Interior's Bureau of Land Management, Minerals Management Service and Fish and Wildlife Service. Additionally, the National Marine Fisheries Service in the Department of Commerce and the Environmental Protection Agency have vital responsibilities for energy development. The Federal Government receives and has received billions of dollars in bonus bids and royalties from the leasing of federal lands. We believe that it is imperative that the government fund these agencies properly so that appropriate environmental and marine mammal and wildlife studies can be carried out. In order to promote scientific research and environmental studies, we recommend that Congress provide additional funding to the Mineral Management Service Environmental Studies Program. Additionally, Shell is strongly supportive of initiatives that allow companies to provide funding to third parties, chosen by the government, that can perform needed environmental analysis and studies when staffing and funding challenges prevent federal agencies from performing these functions in a timely manners.

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1) **How much did your company invest in renewable energy technologies by year and by project over the last 10 years?**

   Answer: As we have testified, globally Chevron has spent more than $2 billion since 2002 on a broad range of renewables and customer energy efficiency projects. Between 2007 and 2009, we have announced plans to spend an additional $2.5 billion on renewable technologies and customer energy efficiency solutions. The detailed breakout of these expenditures is proprietary business information, which we need to keep confidential for competitive reasons.

   Since 2000, Chevron Energy Solutions (CES), a unit of Chevron Corporation, has developed more than 800 projects involving customer energy efficiency or renewable power for the country's education, government and business customers.

2) **How much does your company plan on investing in renewable energy technologies by year in coming years?**

   Answer: Between 2007 and 2009, we have announced plans to spend an additional $2.5 billion on renewable technologies and energy efficiency solutions. The detailed breakout of these expenditures is proprietary business information, which we need to keep confidential for competitive reasons.

3) **Based on the fundamentals of supply and demand, what does your company estimate the price of oil should be were it not for speculation, and other factors? Mr. Simon from ExxonMobil testified that their analysis of fundamental supply and demand suggests a price of oil in the $50-55 range, and prices above that figure are due to speculation, weakening dollar and geopolitical stability. Do you agree or disagree with that analysis?**

   Answer: We believe it is unlikely that speculative financial trading has a significant effect on crude prices over the long term. Many factors influence the price of oil, including supply and demand, perceptions of market trends, geopolitical instability, commodity investments, and the devaluation of the dollar. However, speculation can be a factor in any commodity market, including oil. Over the long term we don't see speculators dominating the market – it is too large. We don't have the ability to quantify the impact of various individual factors that influence the price of crude oil.

4) **What percentage of the current price of oil is a result of speculation?**

   Answer: We believe it is unlikely that speculative financial trading has a significant effect on crude prices over the long term. Many factors influence the price of oil, including supply and demand, perceptions of market trends, geopolitical instability, commodity investments, and the devaluation of the dollar. However, speculation can be a factor in any commodity market, including oil. Over the long term we don't see speculators dominating the market – it is too large. We don't have the ability to quantify the impact of various individual factors that influence the price of crude oil.

5) **How much did your company invest last year in emerging energy technologies in North America and what types of technologies would that include?**

Answer: As we have testified, globally Chevron has spent more than $2 billion since 2002 on a broad range of renewables and energy efficiency. North America accounts for about one half of our global spending. Between 2007 and 2009, we have announced plans to spend an additional $2.5 billion on renewable technologies and energy efficiency solutions. The regional totals and more detailed breakout of these expenditures is proprietary business information, which we need to keep confidential for competitive reasons. *(See Attachment 1: "Chevron Biofuels Research Collaborations")*

Since 2000, Chevron Energy Solutions (CES), a unit of Chevron Corporation, has developed more than 800 projects involving energy efficiency or renewable power for the country's education, government and business customers.

6) **In 2030, what percentage of global energy demand will be met by fossil fuels?**

Answer: EIA's 2007 projection (Reference Case) estimates around 85% of global energy demand will be met by oil, gas and coal. The National Petroleum Council (NPC) Report evaluated various sources and developed a range of 83-87%.
(Source: http://www.npchardtruthsreport.org/)

7) **Do you think that it is important as an energy security issue, to use more of the U.S. reserves of oil and natural gas? What are the best policies to assure our energy independence?**

Answer: U.S. energy policy needs to acknowledge the interdependence of global energy markets, and, that our country is a major energy producer and has the ability to shape our own destiny.

We must continue to bring traditional energy supplies to market, and invest in the critical energy infrastructure this nation needs, even as we are developing alternatives sources of energy. To meet rising world demand, we need all the energy we can develop in every potential form. Diversity of supply is a sign of strength rather than vulnerability. Therefore, we need to improve access to U.S. supplies, promote energy efficiency, secure diversification of U.S. energy supplies and suppliers, rationalize the gasoline supply to make it more efficient, and streamline permitting for major energy facilities.

The NPC study sets forth five core strategies to assist markets in meeting the energy challenges to 2030 and beyond. The United States must:

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1. Moderate the growing demand for energy by increasing efficiency of transportation, residential, commercial and industrial uses.
2. Expand and diversify production from clean coal, nuclear, biomass, other renewables, and unconventional oil and natural gas; moderate the decline of conventional oil and natural gas production; and increase access for development of new resources.
3. Integrate energy policy into trade, economic, environmental, security and foreign policies; strengthen global energy trade and investment; and broaden dialogue with both producing and consuming nations to improve global energy security.
4. Enhance science and engineering capabilities and create long-term opportunities for research and development in all phases of the energy supply and demand system.
5. Develop the legal framework to enable carbon capture and sequestration (CCS). In addition, as policymakers consider options to reduce CO_2 emissions, provide an effective global framework for carbon management, including establishment of a transparent, predictable, economy-wide cost for CO_2 emissions.

8) What percentage of your stock is own by pension plans and retirement accounts?

Answer: Chevron does not have a precise answer to this question – it is not data we track since many shareholders, including the majority of pension plans, hold their shares through third party investment advisers and custodian banks. In these cases the shareholder's identity is not known through our shareholder records. While we believe the percentage is significant, the best validation for this is a recent study published on the topic for the industry at large. Shapiro and Pham estimate that 27% of oil and gas industry shares are held in private and public pension funds, and that another 14% are held in IRA accounts. (Source: Robert J. Shapiro and Nam D. Pham, 2007, *The Distribution of Ownership of U.S. Oil and Natural Gas Companies,* http://www.sonecon.com/docs/studies/0907_WhoOwnsOilCompanies.pdf)

9) Do you support the use of coal-to-liquids as an alternative to traditional petroleum? If not, why not? As a follow up, wouldn't the use of coal-to-liquids significantly increase our domestic supply of fuel?

Answer: As noted earlier, we believe all forms of energy will be needed to meet the world's future demand for energy. Chevron is evaluating coal-to-liquids technology through our Sasol Chevron Joint Venture, using an indirect process that first gasifies the coal, then makes liquids from the gas. This process should result in lower capital costs for facilities, higher energy yields and lower carbon dioxide emissions from the manufacturing process.

In addition, Chevron Energy Technology Company, a Chevron Corporation subsidiary, has formed a research alliance with the Penn State Institute of Energy and the Institute of Environment to research coal conversion technologies. The joint research initiative will focus on technical innovations of clean coal and coal-to-liquid technology.

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An integrated national energy strategy must be developed which addresses our need to expand and diversify production from clean coal, nuclear, biomass, other renewables, and unconventional oil and natural gas; moderate the decline of conventional oil and natural gas production; and increase access for development of new resources.

10) How much bio-fuel and ethanol do you think realistically can be substituted for traditional petroleum?

Answer: We believe that the blending of ethanol up to the legal limit of 10% of the gasoline pool by volume (E-10) is achievable given current technology and infrastructure.

Achieving blending levels outlined in the Energy Security and Independence Act of 2007 requires increased research and development into advanced biofuels that are not developed from food-related feedstock. The required volumes rise to 15.2 billion gallons in 2012 and up to 36 billion gallons by 2022. Advanced biofuels (such as cellulosic biofuel, biomass-based diesel) must be used, along with conventional corn ethanol, to meet annual volume requirements starting in 2009. The annual amount of corn ethanol that can be used to satisfy the requirements is capped at 15 billion gallons beginning in 2015 and advanced biofuels are required to meet remaining volumes through 2022.

It is important to note that, as a practical matter, the technology needed to deliver advanced biofuels at scale doesn't yet exist and is a major challenge. In addition to technology, we need to assess the impact of food-versus-fuel issues, land use constraints, increased irrigation and water requirements, the increased use of pesticides, and other factors.

Blending beyond the 10% limit requires the Environmental Protection Agency to lift this limit and would require considerable infrastructure to provide fuels for vehicles designed to run on higher ethanol concentrations.

11) Are you involved in developing production in Canada's oil sands or Western oil shale? Do you believe those alternatives will become more viable if the price of oil continues to rise?

Answer: Chevron has nine heavy oil leases in place in the Athabasca Region of Northern Alberta. Called the Ells River Appraisal Project, it is comprised of 85,000 acres and has an estimated 5.2 to 9.8 billion barrels of bitumen in place. At the nearby Athabasca Oil Sands Project, Chevron and its partners are producing about 155,000 barrels of bitumen per day and Chevron has committed $2 billion to expand bitumen production, targeting 255,000 barrels per day by 2010. The mine contains more than five billion barrels of mineable bitumen.

The U.S. Department of Energy estimates 1.2 trillion barrels of shale oil in Colorado's Piceance Basin, or about 0.5 to 2.5 million barrels per acre. Chevron's proposal is to test proprietary oil shale technology on a 160-acre Bureau of Land Management lease about 25 miles southwest of Meeker, Colorado. This RD&D (Research, Development and Demonstration) lease is one of only five issued by the federal government in the last 30 years. Our RD&D project is designed to determine if our oil shale technology can result in the economic development of this resource.

12) The American Jobs Creation Act provides a tax credit of up to $1.00 per gallon for the sale and use of "agri-biodiesel" -- biodiesel from virgin agricultural products. The credit is $0.50 per gallon for biodiesel from recycled grease. In addition, the law provides an excise tax credit for biodiesel blends (i.e., biodiesel and conventional diesel). Producers are eligible for one credit or the other, but not both. The Energy Policy Act of 2005 extends these credits through 2008. Do you support making these credits permanent? Do you support increasing these credits?

Answer: We believe that free and open markets for transportation fuels, where all fuels must compete on their own merits, are the best way to deliver the greatest value to our customers. Mandates, subsidies, and tariffs can distort market forces by picking artificial winners and reducing the incentive for innovation.

13) Do you support suspending or reducing the number of "boutique fuel mixes" that each state mandates in order to reduce gas prices in the near future?

Answer: Yes, Chevron encourages careful evaluation of policies that can lead to unintended consequences and create inefficiencies in the gasoline supply system. Today we have over 17 "boutique" fuel requirements across the country, requiring us to blend unique gasoline products for different states and different localities in response to clean air initiatives. More requirements on fuels are being added through additional national and state renewable fuel mandates and proposed climate policies. For example, the federal Renewable Fuel Standard (RFS) imposes a national mandate to include rising levels of corn-based ethanol in our gasoline products and, over time, add significant quantities of cellulosic biofuels. At the same time that we are accommodating this new mandate, several states have proposed or have already established separate renewable fuel mandates. Both state and federal policymakers have proposed legislation to reduce greenhouse gas emissions that again is focused very heavily on the transportation fuels sector and could cause yet more boutiques to be created. We urge you and your colleagues to reflect on how to advance these important national policies without inadvertently disrupting our ability to provide the gasoline and transportation fuels that the United States needs at prices that are affordable. Rationalization of these multiple requirements will reduce complexity in the system by creating at least regional standards so gasoline can move across state boundaries without having to change the formulation, will create greater efficiencies in the fuel supply distribution system, and enhance the industry's ability to resupply areas during supply disruptions.

14) Do you believe that the Energy Independence and Security Act of 2007 went far enough to access US oil and natural gas resources?

Answer: Passage of the Energy Independence and Security Act (EISA) of 2007 is a clear sign that addressing our nation's energy challenges is a top priority for policy makers. Congress must take the momentum developed and pursue additional long-term policies to enhance our energy security. The recent NPC Report contains important policy recommendations that Congress should consider.

Unfortunately, EISA failed to address a number of important public policy issues, including increasing the country's energy supply. It did not expand access to domestic land and Outer Continental Shelf reserves of oil and natural gas. It also failed to provide for increased utilization of coal-based fuels, which can augment conventional domestic oil and gas supplies and reduce imports. The increased use of domestic sources, like petroleum and natural gas will play a critical role in meeting growing demand for decades to come and in enhancing U.S. energy security. While energy efficiency and deployment of renewable energy sources are important elements, increasing America's domestic supply will play a critical role in meeting America's growing energy demand for decades to come.

15) **Are you actively pursing carbon sequestration and Enhanced Oil Recovery in your oil fields and has that work been successful? What more needs to be done in this area?**

Answer: Yes, we need all the energy we can get from every available source. We must continue to bring traditional energy supplies to market, and invest in the critical energy infrastructure this nation needs, even as we are developing alternative sources of energy.

Capturing and storing carbon dioxide in geologic formations (often called carbon sequestration) is among the key technologies Chevron is pursuing to mitigate GHG emissions. Chevron is working with industry partners, academic institutions and government researchers to develop and deploy the technology.

Our Gorgon Liquified Natural Gas project, located in Australia, is one of the most important gas projects in our industry today. In addition to having the potential to supply natural gas to Asia Pacific consumers for the next 40 years, Gorgon will also include one of the world's largest, most advanced carbon sequestration projects. About 3 million metric tons per year of carbon emissions will be sequestered that would otherwise be released into the atmosphere. That's a reduction of 40 percent from business-as-usual emissions. Over the life of the project, we expect approximately 120 million tons of reservoir CO_2 to be safely injected.

The Chevron-operated Rangely field in northwestern Colorado is one of the largest and oldest producing oil fields in North America. Rangely utilizes carbon sequestration technology, applying water and carbon dioxide (CO_2) flooding and other technologies to optimize recovery of its significant reserves.

We are also doing extensive work in Enhanced Oil Recovery. Chevron has formed a research alliance with The University of Texas at Austin to develop new technologies to increase the amount of oil recovered from mature and challenging reservoirs. Conventional production methods have typically recovered about one-third of the oil in place from light oil reservoirs, so applying advanced technologies to increase recovery factors can be an important source of reserve and production growth from existing fields. Technologies such as advanced steamflooding are enabling us to increase the value of existing resources while helping us develop the resources of tomorrow. This year we expect to spend nearly $1 billion on the sophisticated technology and ongoing development activities required to produce as many barrels as possible out of our 100-year-oil Kern River field in California.

16) What is a ballpark figure of how much your company pays in taxes each year?

Answer: As reported to the SEC, Chevron's total tax liability in 2005 was over $30 billion, and in both 2006 and 2007 was over $35 billion.

17) A couple of you mentioned the National Petroleum Council repot "Facing the Hard Truths about Energy" do any of you disagree with the findings of that report?

Answer: The NPC report outlines a comprehensive, integrated and broad based approach to U.S. energy security. We believe the NPC study has given us sound, sensible and achievable solutions.

18) Several of you mentioned the increasing cost of materials, difficulty in finding labor and specifically difficulty in finding engineers and scientists in oil and gas development. What policies do you think would help get the materials and people that you need?

Answer: Today's global energy infrastructure requires substantial ongoing investment to sustain production, tap new sources and meet growing demand. We find ourselves in an extremely competitive global marketplace for all resources which has resulted in sharply rising costs for our industry.

The NPC Report encourages Congress to provide support to those seeking engineering and technical degrees, modify the U.S. tax code and retirement plan regulations to allow part-time work after retirement without penalty, and increase student and immigration quotas for trained professionals in energy and technical fields.

Additionally, we urge Congress to reject punitive measures on our industry. Regardless of intent, these will diminish our ability to invest in the long-term solutions critical to maintaining this country's energy infrastructure and supplies, as well as our ability to develop diverse energy resources in the future.

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19) Is there something in the manufacturing sector that we need to do to help insure that you get the supplies that you need?

Answer: Today's global energy infrastructure requires substantial ongoing investment to sustain production, tap new sources and meet growing demand. We find ourselves in an extremely competitive global marketplace for all resources which has resulted in sharply rising costs for our industry.

We urge Congress to reject punitive measures on our industry, which will diminish our ability to compete with other manufacturers in the global marketplace. We are competing with foreign oil and other manufacturers in an environment where contractors, fabrication facilities and materials such as steel are in short supply. Punitive measures such as windfall profits taxes will diminish our ability to acquire these critical resources and invest in the long-term solutions necessary to maintain this country's energy infrastructure and supplies, as well as our ability to develop diverse energy resources in the future.

20) The International Energy Agency estimates that $22 trillion – in new energy investments will be needed by 2030. Where would that money come from?

Answer: The IEA projects that $22 trillion of investment will be required to meet the world's projected demand growth by 2030. The $22 trillion includes investment across the supply-chain including resource development, transportation, conversion, and distribution. It includes investment in Power Generation, which is expected to account for just over 50% of projected investment requirements. (Source: IEA World Energy Outlook 2007) The global investment needed for the oil and gas sector is about $400 billion per year. Current spending rates are below that. This year, estimates suggest that total global capital investment will approach $300 billion.

Investment will come from a combination of private and government investment targeting the future energy value-chain. Chevron plans to invest roughly $22 billion this year alone across the energy value chain to bring energy to the marketplace, but globally more investment is needed. Much has to come from governments because governments own and control National Oil Companies.

21) What would be required to get biofuels to a commercial scale that they could replace oil in the United States?

Answer: Given that the global demand for energy is growing, it will take contributions from all energy sources — traditional energy, and renewables and alternatives. Biofuels are one of the renewable energy sources that Chevron is actively pursuing. While experts believe that conventional fuels will continue to meet the majority of future demand, biofuels will also be an important part of the fuel supply. The U.S. Energy Information Administration (EIA) projects that even with rapid increases in renewable energy use driven by the Energy Independence and Security Act (EISA) of 2007, renewables will supply about 12 percent of the total U.S. energy demand in 2030.

Chevron's biofuels business is advancing technology and pursuing commercial opportunities relating to the production and distribution of second-generation, or non-food, biofuels. However, there are significant challenges that need to be resolved so that we can generate the kind of production at a scale needed to supplement U.S. demand.

First, there are the issues of technology and feedstock. The technology needed to economically produce non-food biofuels at scale does not currently exist. In addition, there are challenges with sourcing large amounts of non-food feedstock. Chevron believes that these challenges can be overcome, and to do so, we're collaborating with leading laboratories, universities, and commercial partners, including Weyerhaeuser, – as well as conducting our own R&D.

Even if all the technical challenges to second generation biofuels are overcome, there will still need to be an infrastructure to accommodate a commercial-scale industry. Delivering any physical product on that kind of scale requires an enormous infrastructure. Infrastructure is perhaps the most-important and least talked about factor that could constrain second-generation biofuels.

22) In your testimony, several of you point to speculation as a contributing cause of high crude oil prices. I have introduced legislation, the Prevent Unfair Manipulation of Prices (PUMP) Act (HR 594), which would improve oversight of "dark markets" which are currently unregulated by the Commodity Futures Trading Commission. In our December 2007 Oversight and Investigation Subcommittee hearing, we heard testimony that this could reduce the cost of oil by $30 a barrel. Do you believe that speculation in the market is driving up the price of oil? Would you support this legislation?

Answer: We believe it is unlikely that speculative financial trading has a significant effect on crude prices over the long term. Many factors influence the price of oil, including supply and demand, perceptions of market trends, geopolitical instability, commodity investments, and the devaluation of the dollar. However speculation can be a factor in any commodity market, including oil. Over the long term we don't see speculators dominating the market – it is too large. We don't have the ability to quantify the impact of various individual factors that influence the price of crude oil.

Chevron's view is that efficient and transparent markets work, and measures to increase transparency may be helpful. Congress should carefully evaluate any policy proposals to ensure there are no unintended consequences.

We do believe the market would react favorably if America showed real determination to increase access to domestic supplies.

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23) What is the average number of barrels of oil your companies trade each day on NYMEX? On the InterContinental Exchange?

Answer: Our volume traded on the NYMEX is less than one half percent of the barrels traded per day. Our volume traded on the ICE is less than one tenth percent of the barrels traded per day.

24) During the April 1, 2008 hearing, you each spent most of your time complaining about taxes, specifically that the Renewable Energy and Energy Conservation Tax Act (H.R. 5351) passed by the House would repeal $18 billion over ten years in subsidies to your companies. Several times during the hearing, you also said that your companies do not support mandates and subsidies for renewable fuels. Over the next ten years, your companies are expected to make $14.6 trillion. H.R. 5351 would only account for approximately one tenth of one percent of your gross income! How can you insist on retaining these subsidies and tax breaks for your companies while opposing assistance for renewable energy?

Answer: In my testimony, I stated that between 2002 and 2007, Chevron invested approximately $73 billion back into the business to bring new energy supplies to market—investing what we earned. Any increase in taxes on the industry will result in less capital available for new investments in energy projects, at a time when we need more investment.

The Section 199 provision was designed to encourage domestic jobs in various industries. Including Section 199's tax benefits encourages new U.S. oil and natural gas production and investments in new petroleum refining capacity. High-paying U.S. oil industry jobs with excellent health care and other benefits are preserved, and development of domestic energy supplies is encouraged. We believe that the recent punitive proposal to deny this provision to 5 companies is neither good energy policy nor good tax policy.

25) At the American Society of Newspaper Editors Convention on April 14, 2005, the President said, "I will tell you, with $55 [a barrel] oil we don't need incentives to oil and gas companies to explore. There are plenty of incentives. What we need is to put a strategy in place that will help this country over time become less dependent. It's really important. It's an important part of our economic security, and it's an important part of our national security." Today, crude oil prices are double the President's example! Do you agree with President Bush that oil and gas companies do not need incentives to explore when oil is more than $55 a barrel? Do you agree with President Bush that we should instead be investing in renewable energy that will help this country become less dependent on oil?

Answer: Chevron believes that in the current market environment, new tax incentives are not needed for oil and gas exploration.

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We literally need all the energy we can develop and we need to use energy more wisely. This includes oil, natural gas, coal, and nuclear power. It also includes renewables, and, just as important, it includes a focus on energy efficiency.

As we have testified, globally Chevron has spent more than $2 billion since 2002 on a broad range of renewables and energy efficiency. Between 2007 and 2009, we have announced plans to spend an additional $2.5 billion on renewable technologies and energy efficiency solutions.

26) **I have attached internal memos from Chevron, Texaco, and Mobil. The Chevron memo quotes a "senior energy analyst at the recent API convention," stating "if the US petroleum industry doesn't reduce its refining capacity it will never see any substantial increase" in profits. The Texaco memo complains that "supply significantly exceeds demand" leading to "very poor refinery margins and very poor refinery financial results." The Mobil memo advocates keeping a smaller refiner, Powerine, from reopening, stating that a "full court press is warranted in this case." From 1995 to 2002, more than 30 refineries have been closed in the United States. Have any of your companies applied for permits to build new refineries? If yes, how long did it take to obtain the necessary permits? In July 2007, gas prices increased 30 cents overnight in Escanaba, Michigan. There were no supply disruptions or other major events that would influence the price this significantly. Is there any logical explanation why prices would increase 30 cents in that short of time? On May 23, 2007, the U.S. House of Representatives passed H.R. 1252, the Federal Energy Price Gouging Prevention Act by an overwhelming vote of 284 to 141. Please explain why this legislation is not needed, given the significant price increases consumers continue to face.**

Answer: The internal Chevron memo you quote reports on remarks by an external industry analyst at a general industry meeting. We are attaching a letter previously submitted to the House Commerce Committee explaining the background behind this memo and how it has been misconstrued. *(See Attachment 2)*

Regarding the question on refinery capacity, we have not applied for a permit to build a new refinery, but have invested to increase capacity at our existing refineries.

While the number of U.S. refineries has decreased, refinery capacity has increased because refineries have become larger, more complex and more efficient. A combination of regulatory uncertainty, lengthy permitting processes, and multiple regulatory approvals create significant disincentives for modernizing and/or expanding existing refineries or constructing new refineries.

We are investing in our refineries and marketing business to continue to improve our ability to supply the products U.S. consumers need. We are investing $2.3 billion in 2008 in our U.S. refining and marketing assets. Since 2002, we have invested $5.2 billion and we have developed additional gasoline production capacity of more than 1 million gallons of transportation fuel production per day. At present, we are working on major projects at each of our big three U.S. refineries. In California, we are advancing through the permitting process for projects at our El Segundo and Richmond refineries. The process of obtaining these permits at Richmond has taken over three years and is not complete. This is more time than needed to construct a new world-scale state-of-the-art refinery with our partners in India, or complete a major refinery expansion with our partner in Korea. We are also investing in refineries outside the United States, such as Pembroke, Wales, which can produce gasoline to meet U.S. and California specifications.

The local and global forces of supply, demand and competition set the price. Although it is impossible to know exactly why prices in particular markets move as they do because of the myriad complex factors involved, basic economic principles apply: There is upward pressure on prices when demand grows or if a disruption in supply occurs. Crude oil prices are also a key factor in fuel prices because crude is the primary raw material used to produce gasoline. History has shown that over the longer term, gasoline prices generally track the rise and fall of crude oil prices.

Chevron is committed to working with the Congress to build public understanding of the reasons behind gasoline price increases and decreases, which are driven by the market. The term "price gouging" has no precise definition outside of specific state statutes, which define it in a number of different ways. Chevron is committed to comply with these laws. State Attorneys General and the FTC have conducted extensive price-gouging investigations. They are better situated to investigate and determine if there have been any violations of the law, and have found no violations by major refiners. If Chevron learns that a Chevron-branded station violated the law, we will take the appropriate action based on all the circumstances of the particular case. That could include termination of an offending customer's supply contract with Chevron.

27) **In May 2004, the U.S. General Accounting Office released its report, "Effects of Mergers and Market Concentration in the U.S. Petroleum Industry." In this report, GAO found that over 2,600 mergers have occurred in the U.S. petroleum industry since 1990. The GAO also pointed to economic literature that suggests that firms sometimes merged to enhance their ability to control prices. Each of your companies today is the result of significant mergers in the industry. Do you see any more mergers taking place?**

Answer: It is impossible to predict whether we will see more consolidation. Many capital intensive industries have tended to consolidate over time. However, technological developments, changing economics and divestitures have created new competitors. We are now in a period of great change in the energy sector. With significant investment needed to provide new energy supplies and to develop new technologies and alternative fuels, it is likely the industry will continue to evolve, which may include additional merger activity.

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28) In your testimony, almost all of you mention "more domestic drilling" as your top solution to high energy prices. What assurance can you provide that oil and gas from the Arctic National Wildlife Refuge (ANWR), the Outer Continental Shelf (OCS), or other domestic sources would stay in the United States? What is your response to economists that tell us that the oil and gas will likely go to higher priced markets in Japan and elsewhere?

Answer: Crude oil is a globally traded commodity whose price is determined by various factors including supply and demand, perceptions of market trends, geopolitical instability, commodity investments, and the devaluation of the dollar. We don't have the ability to quantify the impact of these factors. What we do know is that every addition to the supply of crude oil, anywhere in the world, will create downward pressure on the price of crude oil.

The reality is that America today depends upon oil and gas to meet its energy needs. The U.S. remains one of the largest oil producers in the world with oil and natural gas liquids production of nearly 7 million barrels per day. However, a combination of rising demand in the United States coupled with declines in our traditional production base for oil and gas have resulted in increasing levels of foreign imports, particularly for transportation fuels. In 2007, the U.S. imported 13.5 million barrels per day of crude oil and petroleum products or roughly 65 percent of total U.S. consumption. U.S. imports of crude oil reached about 10 million barrels per day in 2007 or 73 percent of net input into U.S. refineries.

However, America can become more energy secure by reducing our dependence on imported foreign oil. That is a policy choice. By developing more of our own resources, we send a message to the rest of the world that we are determined to do our part to increase energy supplies.

29) In May 2006, the Energy and Commerce Committee held a hearing on gas prices, and we discussed the crack spread, or the difference between a barrel of crude oil and the refined product. At this hearing, the average crack spread for a refinery in 2006 was estimated to be about $20 to $30 a barrel by Howard Gruenspect, the Deputy Administrator at the Energy Information Administration. Mr. Gruenspect testified that a crack spread of $8 or $9 is sufficient to cover refining expenses and provide a reasonable profit to the facility. What is your current crack spread at the refineries your companies operate? Why have your companies scaled back their refinery expansion plans to keep crack spreads high?

Answer: Chevron considers the following industry benchmark refining margins to be the most relevant to Chevron's U.S. refining business:

Responses Submitted by Chevron to Follow-up Questions from the April 1, 2008 Hearing by the House Select Committee on Energy Independence and Global Warming

Refining Margin Benchmark	1st Qtr. 2008
U.S. West Coast Blended 5-3-1-1 (50% Arab Medium, 25% Arab Extra Light, and 25% Alaska North Slope)	$20.39
U.S. Gulf Coast Maya 5-3-1-1	$26.35

Chevron's realized refining margins in the first quarter of 2008 were lower than these industry indicator margins due to refinery downtime and other factors.

Chevron has not scaled back refinery expansion plans in order to affect refining margins In fact, we have increased capacity over the last two years by over 1 million gallons per day, and we are actively pursuing additional projects to increase the efficiency and refining capacity of our U.S. refineries.

There is simply no basis for the allegation that refiners are guilty of price manipulation. In its comprehensive 2006 *Investigation of Gasoline Price Manipulation and Post-Katrina Gasoline Price Increases*, the Federal Trade Commission reported:

> "Our investigation uncovered no evidence indicating that refiners make product output decisions to affect the market price of gasoline. Instead, the evidence indicated that refiners responded to market prices by trying to produce as much higher-valued products as possible, taking into account crude oil costs and other physical characteristics."

The FTC report also found that:

> "Refiners appear to make capacity expansion decisions based on internal financial criteria and long-term forecasts about market conditions. No evidence suggested that, when making these decisions, refiners take into account any effect their capacity additions will have on prices."

Of course, gasoline prices have risen since the FTC issued that Report. But today's higher fuel prices are explained entirely by the even greater increases in global crude oil prices. During the last three quarters Chevron's U.S. Downstream sector (refining, marketing and transportation) incurred a loss of $161 million, due primarily to the inability to recover higher crude oil costs.

30) Please provide a list of oil and gas leases currently in the possession of your company and its subsidiaries, and give a status report as to the state of the production of each of these leases.

Answer: We currently hold a total of 2139 Federal leases and 1453 of them are considered developed. The following table details the number and percentage of these leases that are developed and held by production vs. those that are considered undeveloped, broken out by onshore and offshore.

Responses Submitted by Chevron to Follow-up Questions from the April 1, 2008 Hearing by the House Select Committee on Energy Independence and Global Warming

Note the relatively larger percentage of offshore leases currently characterized as undeveloped (though not inactive). This reflects several factors, including; a larger percentage of newer leases in early evaluation phases (it can take over a decade to develop a prospect) and the greater challenges involved developing offshore infrastructure to support discoveries. Further, over 10 percent of our "undeveloped" offshore leases are classified as "non-producing within a unit". In this case production of a reservoir common to the unit may occur from facilities on one or only a few of the unitized leases. While the resource associated with the lease is actually being produced, the data we submit to the SEC classifies the lease acreage as undeveloped.

CHEVRON FEDERAL OIL & GAS LEASES						
			DEVELOPED	DEVELOPED - %	UNDEVELOPED	UNDEVELOPED - %
ONSHORE	1343	63%	1155	86%	188	14%
OFFSHORE	796	37%	298	37%	498	63%
TOTAL	**2139**	**100%**	**1453**	68%	**686**	32%

Most of Chevron's undeveloped leases are located in water depths between 4,000 and 10,000 feet where there is no infrastructure to produce hydrocarbons, and most of Chevron's exploratory activity is in ultra-deepwater (greater than 6,000 feet) areas of the Gulf of Mexico. Technology is being developed to produce newly discovered resources in ultra-deepwater, but it takes years to design, build, test, and install this new equipment. In many cases 10 year primary lease terms are too short to allow orderly development in frontier areas such as ultra-deepwater.

Onshore or offshore, our consistent practice is to conduct a thorough evaluation, followed by development where viable, of every lease we hold. Not every lease has recoverable resources—leases for those properties that are unproductive are relinquished once we have determined that commercial quantities of oil and gas are not available.

31) As fuel prices rose over the past 6 years, has American demand decreased? Why or why not has this occurred? If gas taxes were increased, do you think demand would decrease? Did this happen in European countries when then imposed large gas taxes?

Answer: The accelerated increase in demand for energy since 2004 has reduced the global spare capacity of crude oil, creating a tighter relationship between supply and demand and heightened concerns in markets around the world. In the U.S., consumers have begun to respond to the high fuel prices by using less. Figures from the EIA suggest that petroleum product demand in the U.S. has fallen 4.4 percent over the first three months of the year, compared with the same period last year.

As it is impossible to know exactly why prices in particular markets move as they do because of the myriad complex factors involved, it is also impossible to determine how demand will react to a myriad of complex factors.

The marketplace forces of supply, demand, and competition determine the price of gasoline. Chevron takes the market as we find it and we price our products competitively in each market we serve. Increased taxes would add to the price of gasoline, and therefore could impact gasoline demand.

As far as Europe is concerned, diesel penetration of the European passenger car markets started around the end of the 1980s, when technological innovations improved the comfort and driveability of diesel cars. It is also our understanding that a shift in public policy drove gasoline taxes higher, creating a huge incentive for diesel powered vehicles, which further contributed to the "dieselization" of the automobile industry in Europe.

32) At current projections, when will your current reserves be depleted?

Answer: Chevron's proved oil & gas reserves, as defined by the U.S. Securities & Exchange Commission, total 10,777 million barrels of oil equivalent. This would last roughly 11.4 years at 2007 rates of production.

Chevron Reserves to Production Ratio	2007
Oil & Gas Production MMB/D*	2.6
Oil & Gas Production MMBY*	946.0
Proved OEG Reserves (MMBs)	10,777
Reserves to Production Ratio	**11.4**

*Per SEC Definition

However, proved reserves only capture a fraction of Chevron's total resource portfolio. Chevron's total oil and gas resource portfolio is estimated to be 62.58 billion barrels of oil equivalent. Resource is defined as unrisked proved, probable and possible reserves plus potential recoverable resources contingent on commerciality, including oil volumes associated with Athabasca Oil Sands mining. Crude oil extracted through bitumen mining operations is not considered to be an oil and gas producing activity by the Securities and Exchange Commission.

The long-term viability of our business depends on our success in implementing the massive investments required to transfer these resources into recoverable proved reserves, and ultimately into production.

33) When do you expect underdeveloped countries will reach a level to where they will begin to significantly buy oil for use? How will this affect supply and fuel prices?

Answer: Today the developed economies in North America, Europe, and Asia account for roughly 56% of the world's oil consumption. It will be some time before under-developed countries rival these nations in terms of absolute levels of consumption. However, developing economies (non-OECD) have accounted for nearly 91% of the growth in oil demand since the start of this decade. China alone has made up nearly 32% of the rise in global oil demand since 2000.

The emergence of significant levels of demand growth across these developing economies has been one of the critical factors shaping global oil market dynamics and prices this decade.

34) If all conventional, alternative, and unconventional sources of oil in the U.S. were to be developed, how long would the supply last based on current estimates of increased usage?

Answer: This is a difficult question to answer given the broad definition of conventional, alternative, and unconventional sources of domestic oil. There is great uncertainty regarding technology and future development to pinpoint the future potential of resources like second generation biofuels, coal-to-liquid (CTL), shale, etc. Some of these technologies compete in other markets and therefore it is unclear exactly how much resource will be devoted to liquid fuel development. Shale and coal development will also hinge future environmental policy (CO_2) and permitting from the federal to local level.

The U.S. holds 2% of the world's conventional oil reserves and 3% of the world's natural gas reserves. However, the U.S. holds huge undeveloped resources of natural gas, oil and two promising unconventional sources of liquids fuels; coal and oil shale. Of the world's estimated 4 trillion barrels of oil equivalent (BOE) for coal, the U.S. has a 28% share or 1.1 trillion BOE. Of the world's estimated 1.1 trillion BOE proved reserves base of oil shale, the U.S. has a 58% share or over 600 billion BOE.

Perhaps a more concrete example would be to look at conventional oil resources in the U.S. currently off-limits to development. The U.S. Minerals Management Service estimates that the 85% of acreage of the Outer Continental Shelf off-limits to oil & gas development contains:

- 19 billion barrels of oil - enough to replace OPEC imports for 11 years
- 86 trillion cubic feet of natural gas - enough to meet current residential use for 18 years

35) Please describe to this committee your short, middle, and long-term plans for oil and renewable energy development.

Answer: We are actively responding to the energy demand of the United States and countries around the world—investing aggressively to develop a diversified portfolio of energy supplies to meet today's and tomorrow's needs. Our activities span a diverse portfolio of energy interests, including traditional oil and gas, renewables, alternatives, energy efficiency services, and research and development in future energies. Between 2002 and 2007, Chevron invested approximately $73 billion back into the business to bring new energy supplies to market—investing what we earned. Some $22 billion of that sum was invested in our U.S. operations.

Globally, Chevron currently has 40 major capital oil and natural gas projects in the planning, engineering or development stage, each with a net Chevron share of the investment over $1 billion. These projects are critical to supplying the energy that the world needs and will be important to closing the gap between supply and demand, which is key to addressing the challenge of high prices. Out of this queue of 40 major supply projects, eight are located in the United States. And there are many other upstream projects under $1 billion that will yield significant production.

Since 2002, Chevron has spent more than $2 billion to develop renewables and energy efficiency services. Between 2007 and 2009, our spending on renewable technologies and energy efficiency solutions will be an additional $2.5 billion.

36) You note that you blend ethanol into almost 40% of the gasoline that you sell in the United States – how has the price of ethanol fluctuated over the last few years and what impact has that had on the price of gasoline overall?

Answer: Ethanol is an important component for gasoline supply, and is therefore a factor in fuel costs but to a much lesser extent than crude oil because of the low ratio of ethanol in gasoline. Inasmuch as ethanol adds to the supply of gasoline, the fundamental laws of supply and demand predict a moderating influence on prices. If the cost of ethanol were to significantly increase or decrease, it could have a corresponding effect relative to the price of gasoline at that time. But quantification is virtually impossible due to the many other forces affecting both supply and demand.

37) What type of ethanol are you using for your blends? And what types of "next-generation biofuels" are you considering?

Answer: Chevron is currently not a producer of ethanol and, therefore, to meet our system requirements we purchase anhydrous ethanol from a variety of domestic and international producers and distributors. Domestic ethanol supplies are produced mostly from corn while international supplies are produced mostly from sugar cane.

Next generation biofuels under research at Chevron include cellulosic ethanol, biomass-based diesel and other finished liquid fuels, and biomass-based crude and intermediate products that can be further processed in our existing refining infrastructure.

38) In your testimony you note that you are the world's largest geothermal energy producer. Where are you producing that energy? What would make the U.S. a viable site for geothermal production?

Answer: We currently operate geothermal power facilities in Indonesia and the Philippines, with a total installed capacity of 1,273 megawatts. The U.S already has geothermal power plants, primarily in the western U.S. where geothermal reservoirs exist. While large power generation facilities are limited to locations where underground reservoirs of hot water and steam are available, Chevron is also evaluating technologies that extract geothermal energy from nontraditional sources. These technologies can be integrated into existing operations to minimize resource waste, and generate renewable baseload power for operating cost offsets and/or supplying power to the grid.

39) I am told that you have actually used solar panels to provide energy for drilling for oil in some of your locations. Could you expand on your experience with that?

Answer: The Solarmine project, installed on six acres of Chevron oilfield property near Bakersfield, California, generates peak power of approximately 500 kilowatts, or about 930,000 kilowatt-hours of clean energy annually. The purpose of the project has been to gain experience in the design and development of a flexible photovoltaic (PV) system and collect data to evaluate the system's performance and benefits. The system is made up of 4,800 Uni-Solar PV-128 photovoltaic modules installed on south-facing racks. At the time the system was completed in early 2003, it was the largest array of amorphous-silicon solar technology in the world, offsetting 326 tons of CO2 emissions annually. The project is connected to the local electric distribution system and provides power to oil-well pumping units and processing plants in Chevron's Midway-Sunset oil field. We are also evaluating alternative solar thermal systems to see whether they can be useful in generating heat for oil production.

40) As for the projects where Chevron has provided solar energy, what has been your experience with consistency of available power generation?

Answer: When Chevron develops a solar project, we utilize various models developed by the National Laboratories to estimate the level of output for a solar project. We enter in the site specific and project specific attributes such as the system size, location, orientation, tilt, module and inverter characteristics, etc. to estimate the future output of the facility. We then track the actual performance of the solar system utilizing data monitoring systems. We have consistently found that the actual output of the solar system meets or exceeds the expected output of the system. This assumes that the installation itself is properly designed, engineered, and maintained based on site specific criteria and that there is no shade on the modules during the daytime hours.

The energy produced on an annual basis is fairly predictable and also reasonably stable over time. From an electric utility's perspective, the question of consistency may be regarded quite differently as the output of a solar facility can entertain wide variations multiple times in the same day, and even during daytime hours, due to weather patterns, clouds, or other factors. Thus, the "capacity" value of solar is somewhat variable over the period of a day, but the 'energy" value" is generally quite consistent over the long term.

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41) On Page 2 of your testimony, you emphasize that "strong global demand" and "weak U.S. dollar" have driven up oil prices – what countries have soaring demand for oil and how does that compare to the demand for oil in the United States?

Answer: The U.S. is the world's single largest consumer of oil accounting for roughly 24% of global consumption or 20.7 million barrels per day. The U.S. has only accounted for about 7% of the rise in global oil demand since 2000, whereas developing economies have made up nearly 91% of the growth in oil demand since the start of the decade.

The emergence of significant levels of demand growth across these developing economies has been one of the critical factors shaping global oil market dynamics and prices this decade.

China has been the single largest contributor to oil demand growth this decade accounting for 32% of the increase in demand since 2000. In absolute terms, China consumes 7.9 million barrels per day.

The Middle East has accounted for nearly 24% of the increase in oil demand since 2004. The IEA projects that the region will account for 30% of the increase in oil demand this year. The emergence of the demand growth in the Middle East has also been a significant event in the oil market. Higher internal demand in the region means less available for export from the Middle East—a key oil supplying region.

42) On Page 3 of your written statement you say "The Middle East is also in the middle of a substantial investment cycle, a process that has kick-started oil demand growth in the face of rising oil prices." Could you explain that statement further?

Answer: Higher oil prices have resulted in generating significant investment in Middle East oil resources for producers. This has stimulated economic growth across the region through higher levels of domestic investment in projects and infrastructure. This investment phase has prompted higher demand for raw materials, including energy, across the region.

The Middle East has accounted for nearly 24% of the increase in oil demand since 2004. The IEA projects that the region will account for 30% of the increase in oil demand this year. Most Middle East governments subsidize oil consumption; therefore demand growth has not been heavily impacted by the rising price of crude oil on the global market.

43) On Page 7 of your testimony, you talk about your project to make biofuels from non-food sources – what sources do you think hold the most potential?

Answer: Chevron is researching the potential of a wide variety of non-food and non-feed biomass sources. We are evaluating forestry resources and by-products, switchgrass, purpose-grown energy crops such as miscanthus, energy cane, sorghum, jatropha, and municipal solid waste and other recovered fibers. In addition, algae may hold promising long-term potential and the added benefit of not requiring large amounts of tillable land to achieve commercial scale.

At this stage of our research, it would be premature to know which one or combination of sources hold the most potential for large scale non-food commercial biofuel production.

44) **What has your experience with hydrogen stations? What kind of investment would it take to update our infrastructure nationally is hydrogen becomes a viable option for transportation fuel in the long term?**

Answer: Chevron currently operates a total of five hydrogen energy demonstration stations in California, Michigan and Florida. Hydrogen vehicle technology is still in the demonstration phase. Despite progress, major hurdles of high fuel cell costs, on-board hydrogen storage costs and limits, and high costs for dispensed hydrogen remain. Until advanced hydrogen production and storage technologies for retail use are developed it's difficult to estimate the costs of deploying hydrogen infrastructure at commercial scale. We expect the industry to continue demonstrations and niche applications including some use by transit buses within the next five years, but significant penetration into the Light Duty Vehicle market seems likely to be decades away.

Continuing progress in other vehicle technology and fuel alternatives, and the desire for nearer-term solutions has moved hydrogen out of the spotlight. Alternatives such as hybrid-electric gasoline or diesel vehicles do not present the barriers of hydrogen, can approach overall fuel cell vehicle energy efficiency, continue to improve, and are commercial now. Hydrogen use in internal combustion (IC) engines is quite well demonstrated, but engine efficiencies are not necessarily better than diesels. NOx emissions controls may still be required, and hydrogen storage and fuel costs are high. In addition, there remains a concern about hydrogen safety in routine fueling by the public.

45) **You note that you are investing in a refinery in Pembroke, Wales which can produce gasoline to meet US and California specifications. Why not build this refinery in the United States?**

Answer: Upgrading and expanding existing refineries has been more efficient and practical in the US than building new refineries. Over the last two years or so, Chevron has increased its gasoline production capacity by over 1 million gallons per day (27,000 barrels per day) through capacity additions at existing refineries. We are currently seeking permits to both our Richmond and El Segundo, California refineries for further production enhancements and increased reliability. Pembroke, Wales, an existing Chevron refinery, already had the ability to manufacture U.S. and California grade gasoline without significant modifications and is being used to back up current production in case of a major supply disruption as well as potentially supplement future production if demand warranted.

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46) **I applaud your emphasis on energy efficiency within your own company. How much money do you estimate that you have saved through increasing your energy efficiency?**

Answer: Chevron is 27% more efficient in 2007 than we were in our base year of 1992. Chevron spent about $5 ½ billion dollars on energy consumption in 2007. Had we not improved and continued at the 1992 efficiency level we would have spent about $7 ½ billion in 2007 which is about $2 billion dollars more than we actually spent.

47) **On page 10 of your testimony, you state, "moderate the growing demand for energy by increasing efficiency of transportation, residential, commercial and industrial users." What other incentives would you recommend?**

Answer: The statement made on page 10 is in reference to the NPC Report's recommendation that policies are needed to promote energy efficiency such as the following: encourage states to implement and enforce more aggressive energy efficiency building codes; establish appliance standards for new products; update federal appliance standards on a regular basis; have the DOE conduct and promote research, development, demonstration, and deployment of industrial energy efficiency technology and best practices; and permanently extend the R&D tax credit to spur private research and development investments.

48) **What would you estimate the cost per gallon of gasoline associated with the financial sector's "flight to commodities"?**

Answer: We don't have the ability to quantify the impact of various factors that influence the price of crude oil, including supply and demand, geopolitical instability, commodity investments, and the devaluation of the dollar.

The local and global forces of supply, demand and competition set the price of gasoline. The major influence on gasoline price increases in the recent year has been increases in the price of crude oil. History has proven that over the longer term, gasoline prices generally track the rise and fall of crude oil prices.

49) **You state on page 1 of your testimony," Chevron is a leading producer of renewable energy. We're the world's largest producer of geothermal energy." How many people do you employ in your renewable energy division or in other words, how many "green collar" workers does Chevron currently employ?**

Answer: Our geothermal business employs over 900 full-time employees (both national plus expatriate) in Indonesia and the Philippines.

In addition, Chevron employs over 500 employees in operations related to energy efficiency, and renewable energy development and commercialization.

Responses Submitted by Chevron to Follow-up Questions from the April 1, 2008 Hearing by the House Select Committee on Energy Independence and Global Warming

50) On Page 11 of your testimony, you bring up the issue of boutique fuels – you mentioned that there are 17 boutique blends across the country. Obviously there are some seasonal issues with blends, but what do you think is the appropriate approach to or number of boutique fuels?

Answer: Today we actually have over 17 "boutique" fuel requirements across the country, requiring us to blend unique gasoline products for different states and different localities. More requirements on fuels are being added through renewable fuel mandates and proposed climate policies. For example, we are under a mandate to include rising levels of corn-based ethanol in our gasoline products and, over time, add significant quantities of cellulosic biofuels. At the same time that we are accommodating these new mandates, policymakers have proposed legislation to reduce greenhouse gas emissions that again is disproportionately burdensome on the transportation fuels sector. We urge you and your colleagues to reflect on how to advance these important national policies without inadvertently disrupting our ability to provide the gasoline and transportation fuels that the United States needs. Rationalization of these multiple requirements will reduce complexity in the system by creating at least regional standards so gasoline can move across state boundaries without having to change the formulation, create greater efficiencies in the fuel supply distribution system, and enhance the industry's ability to resupply areas during supply disruptions.

51) Mr. Robertson (Chevron), in your testimony, you say that given the renewable fuels standard in the Energy Independence bill, Chevron canceled work on a major refinery expansion due to "uncertainty over how much additional U.S. refining capacity may be needed to meet future US demand." But you also note in your testimony that demand for oil will continue to remain the same. How can you claim that you won't need this refinery expansion when you also say that "we literally need all the energy we can develop?" Why are you using renewable fuels as an excuse for not building more refinery capacity?

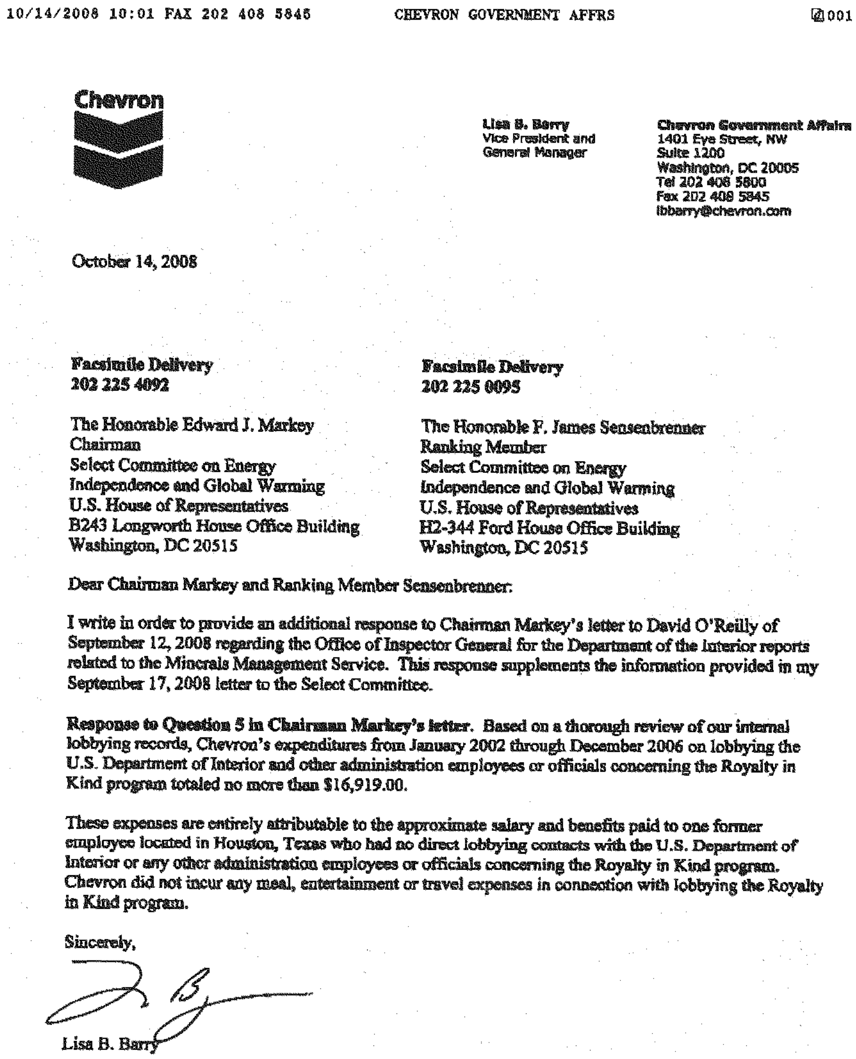
Answer: We believe the U.S. refined petroleum market is currently well supplied to meet demand. Chevron has a number of projects underway at existing refineries to help improve reliability and efficiency, and overall performance which will also help meet future growth needs. Over the last two years or so, Chevron has increased its gasoline production capacity by over 1 million gallons per day through capacity additions. Current and planned projects at Chevron refineries in the U.S. are projected to increase total gasoline production by about another 800,000 gallons/day.

Future investments must take into account market forces, market direction, and government policies – for example, the renewable fuels program creates uncertainty over how much additional petroleum refining capacity will be needed in the U.S. Nonetheless, we are investing $2.3 billion this year in our U.S. refining and marketing business.

Responses Submitted by Chevron to Follow-up Questions from the April 1, 2008 Hearing by the House Select Committee on Energy Independence and Global Warming

Additionally, it can take years to get the permits even for modernization projects that allow our operations to run more reliably and efficiently. For example, such a project at our refinery at Richmond, California is currently in the fourth year of the permit application process.

Globally we need all the energy we can develop and the U.S. needs to do its share. To the extent that we can reduce the declining rate of oil production in the U.S., we can reduce imports of oil.



Chevron

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October 14, 2008

Facsimile Delivery
202 225 4092

The Honorable Edward J. Markey
Chairman
Select Committee on Energy
Independence and Global Warming
U.S. House of Representatives
B243 Longworth House Office Building
Washington, DC 20515

Facsimile Delivery
202 225 0095

The Honorable F. James Sensenbrenner
Ranking Member
Select Committee on Energy
Independence and Global Warming
U.S. House of Representatives
H2-344 Ford House Office Building
Washington, DC 20515

Dear Chairman Markey and Ranking Member Sensenbrenner:

I write in order to provide an additional response to Chairman Markey's letter to David O'Reilly of September 12, 2008 regarding the Office of Inspector General for the Department of the Interior reports related to the Minerals Management Service. This response supplements the information provided in my September 17, 2008 letter to the Select Committee.

Response to Question 5 in Chairman Markey's letter. Based on a thorough review of our internal lobbying records, Chevron's expenditures from January 2002 through December 2006 on lobbying the U.S. Department of Interior and other administration employees or officials concerning the Royalty in Kind program totaled no more than $16,919.00.

These expenses are entirely attributable to the approximate salary and benefits paid to one former employee located in Houston, Texas who had no direct lobbying contacts with the U.S. Department of Interior or any other administration employees or officials concerning the Royalty in Kind program. Chevron did not incur any meal, entertainment or travel expenses in connection with lobbying the Royalty in Kind program.

Sincerely,

Lisa B. Barry

John E. Lowe
Executive Vice President
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ConocoPhillips

June 26, 2008

The Honorable Edward J. Markey
Chairman, the Select Committee on Energy Independence and Global Warming
U.S. House of Representatives
Longworth House Office Building
Washington, D.C. 20515

Dear Representative Markey:

I am attaching our company's responses to the written questions from members of the Select Committee on Energy Independence and Global warming forwarded to us from your staff on June 3, 2008. We appreciate you extending the response deadline to June 26, 2008 as it allowed us to spend the time required to address some of the more complex questions.

Please direct any further questions on this response to Jeff Reamy, in our Washington, D.C. office. His telephone number is (202) 833-0922.

We appreciate the opportunity to share our views on the energy security challenges that the U.S. is facing and what our beliefs on what this nation needs to do about it. We look forward to further dialogue with your committee on this important topic.

Sincerely,

John E Lowe

John E. Lowe

Questions from Select Committee on Energy Independence and Global Warming

1) **How much did your company invest in renewable energy technologies by year and by project over the last 10 years?**

Several government forecasts show that fossil fuels will still be meeting about 80 percent of the world's energy needs in 2030. ConocoPhillips invested $57 billion between 2003 and 2007 in developing new conventional, unconventional and alternative energy supplies as we will need all of these sources to satisfy energy demand. That figure represents a reinvestment rate on average of 106 percent of net income over this time period.

The proportion of capital devoted to alternative energy investments seems small only because of the vast scale of our existing oil and natural gas businesses. Our objective is to develop new technologies that can compete with conventional hydrocarbons and reduce their carbon footprint. If we advance the technologies as planned, this could lead to multi-billion dollar projects.

Over the last five years, ConocoPhillips has invested nearly $700 million in alternative energy technology, with over $200 million on the renewable portion. Reliable data is not available prior to the merger between Conoco Inc. and Phillips Petroleum Company.

$MM	2003	2004	2005	2006	2007
CTL/GTL	29	58	39	25	24
Heavy Oil/Wind/Non Fossil Fuels/Hydrogen	39	26	35	46	41
Other Technology	50	56	61	72	90
Total	$118	$140	$135	$143	$155

We are engaged in a substantial amount of activity in the alternative energy arena and we summarize it below:

Renewable energy – ConocoPhillips is already a large blender of conventional ethanol in the United States. As the nation's second-largest refiner and fuels producer, during 2007 our marketers in the United States sold about 425 million gallons of ethanol, equivalent to a nationwide blend rate of 4.7 percent. Approximately 55 percent of our gasoline sales contain ethanol. Additionally, we are rapidly expanding our U.S. ethanol blending capabilities. Since 2005, we spent $55 million on ethanol blending facilities at our terminals. We now have capability to blend ethanol at 120 terminals (including proprietary and third-party terminals) and are evaluating additional expansions. We are selectively adding biodiesel blending capabilities, although this fuel is currently priced higher than petroleum-based diesel fuel, and the economics of blending are challenged.

E-85 fuel is being marketed under our branded canopy in a number of states with over 2,500 potential sites, provided the marketer meets certain image, safety and fuel-quality guidelines. Biodiesel is also being test marketed under our branded canopy, with under-the-canopy sales of unbranded B11 in Illinois and of branded B5 in certain farm states, again provided that the marketer meets specific image, safety and fuel-quality guidelines. Over 800 branded sites could potentially pilot market biodiesel in certain states.

The company is also engaged in the development and production of new biofuels that have a better environmental footprint than existing sources. We currently produce renewable diesel fuel at our Whitegate refinery in Ireland using vegetable oils as a feedstock, and are test manufacturing the process at the Borger refinery (a joint venture with EnCana) in Texas as part of our arrangement with Tyson Foods to utilize by-product animal fat as a feedstock. The technology is performing well, but the economics are threatened by rising raw material costs and the prospective loss of federal tax credits that are available to competing biomass-based diesel fuels.

ConocoPhillips conducts or funds internal and external research on new biomass fuels and has a joint development agreement with Archer Daniels Midland to develop fuels from agricultural waste. We have a major relationship with Iowa State University to research all phases of biofuels, and are a founding member of the Colorado Center for Biorefining and Biofuels, a cooperative research and educational center devoted to the conversion of biomass-to-fuels and other products.

Further, ConocoPhillips has created an internal group dedicated to evaluating opportunities to invest in solar, wind and geothermal power projects.

Alternative automotive technology – ConocoPhillips has participated in the FreedomCAR and Fuel Partnership with the U.S. Department of Energy, automobile manufacturers and other fuel providers since 2003. We are also working to facilitate wider use of electric vehicles by developing high-performance materials for lithium-ion batteries, a critical component in these vehicles.

Gasification – ConocoPhillips' E-Gas™ technology is a leading, commercially proven gasification technique. We are developing projects based on this technology and licensing it to others to utilize in producing synthetic natural gas, electrical power and a variety of chemicals. We are actively conducting feasibility studies on two gasification projects for equity participation. The first one is in conjunction with Peabody Energy in Kentucky, which would use the ConocoPhillips proprietary E-Gas™ technology to produce syngas from a blend of coal and petroleum coke (approximately 10,000 tons per day), which would then be converted into pipeline quality methane (natural gas, 50-70 billion cubic feet per year). The second project is at the ConocoPhillips Sweeny refinery in the Texas Gulf Coast. This project plans to produce syngas from refinery-sourced petroleum coke (about 5000 tons per day) for use in the associated cogeneration power plant, or in producing methane and hydrogen. These will be among the largest coal or coke-fueled gasification facilities in the world and could both be operational in the 2014-2016 timeframe if the studies prove them to be economically viable. The total expected gross capital costs are estimated at up to $7 billion. Options for carbon capture and sequestration are being evaluated for both of these projects.

Heavy oil and unconventional oil and natural gas – ConocoPhillips is presently undertaking significant research to improve the recovery of heavy oil and unconventional oil, such as oil shale, and improve energy efficiency throughout the production, transportation and processing value chain. We are also undertaking research and development focused on reducing their environmental footprint in terms of greenhouse gas emissions, water and land use.

Other focus areas for our research and development efforts include improving recovery of challenged natural gas and developing methods to commercially produce methane hydrates.

Carbon dioxide capture and storage and water usage – ConocoPhillips believes that development of carbon capture and storage (CCS) technology is essential in that it will improve the environmental sustainability and acceptability of available fossil fuel resources. The company funds internal research as well as university research programs in the United States, Canada, Australia, Norway and the United Kingdom that are investigating CCS technology and how it can be customized to meet our industry's needs and the needs of our specific sites. We are in the planning phases for selecting several possible CCS sites in the United States and other countries.

ConocoPhillips believes that reducing the footprint of energy production operations on water resources will help improve the sustainability of both conventional and alternative energy sources. We are measuring our freshwater usage and developing detailed water assessments of selected business units, bringing greater focus to water management as a fundamental component of business planning. In addition to technology work underway in our existing Oklahoma laboratories, in cooperation with General Electric, we recently announced the establishment of the Qatar Water Sustainability Center, with the long-term vision that it will become a corporate center of excellence for water-related technologies.

2) **How much does your company plan on investing in renewable energy technologies by year in coming years?**

The ConocoPhillips current long range plan includes $100-$150 million per year for renewables and a total technology budget of approximately $500 million per year.

ConocoPhillips is already a large blender of conventional ethanol in the United States. As the nation's second-largest refiner and fuels producer, during 2007 our marketers in the United States sold about 425 million gallons of ethanol, equivalent to a nationwide blend rate of 4.7 percent. Approximately 55 percent of our gasoline sales contain ethanol. Additionally, we are rapidly expanding our U.S. ethanol blending capabilities. Since 2005, we spent $55 million on ethanol blending facilities at our terminals. We now have capability to blend ethanol at 120 terminals (including proprietary and third-party terminals) and are evaluating additional expansions. We are selectively adding biodiesel blending capabilities, although this fuel is currently priced higher than petroleum-based diesel fuel, and the economics of blending are challenged.

E-85 fuel is being marketed under our branded canopy in a number of states with over 2,500 potential sites, provided the marketer meets certain image, safety and fuel-quality guidelines. Biodiesel is also being test marketed under our branded canopy, with under-the-canopy sales of unbranded B11 in Illinois and of branded B5 in certain farm states, again provided that the marketer meets specific image, safety and fuel-quality guidelines. Over 800 branded sites could potentially pilot market biodiesel in certain states.

The company is also engaged in the development and production of new biofuels that have a better environmental footprint than existing sources. We currently produce renewable diesel fuel at our Whitegate refinery in Ireland using vegetable oils as a feedstock, and are test manufacturing the process at the Borger refinery (a joint venture-owned facility with EnCana) in Texas as part of our arrangement with Tyson Foods to utilize by-product animal fat as a feedstock. The technology is performing well, but the economics are threatened by rising raw material costs and the prospective loss of federal tax credits that are available to competing biomass-based diesel fuels.

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Further, ConocoPhillips has created an internal group dedicated to evaluating opportunities to invest in solar, wind and geothermal power projects.

3) **Based on the fundamentals of supply and demand, what does your company estimate the price of oil should be were it not for speculation, and other factors? Mr. Simon from ExxonMobil testified that their analysis of fundamental supply and demand suggests a price of oil in the $50-55 range, and prices above that figure are due to speculation, weakening dollar and geopolitical stability. Do you agree or disagree with that analysis?**

The price of crude oil is set in the free market. It is not possible for anyone to know what crude oil prices "should be" in an unregulated market or "would be" under a specified set of conditions.

In a free and competitive market, long-term oil prices will settle at a level sufficient to provide incremental supply needed to satisfy demand. We believe that the marginal reserve replacement cost today is higher than the range indicated above. Some financial analysts believe it is currently at least $85 to $90 per barrel and that it is continuing to rise. In the short-term, other market influences can result in temporary prices above or below the long-term "equilibrium" level.

One of the major reasons for high marginal replacement costs is that major energy companies such as ConocoPhillips have direct access to only 7 percent of the world's oil and natural gas resources, down from 85 percent in the 1960s. We are being forced to develop resources that are in very mature and / or high cost areas or are technologically challenging (e.g., deep water, high sulfur natural gas, heavy oil). Congress can help reduce long-term reserves replacement cost by opening up new areas in the U.S. with lower cost structures than what we are developing today.

4) **What percentage of the current price of oil is a result of speculation?**

We believe some investors are diversifying financial risks in their stock and bond portfolios by investing in crude oil and other commodity futures but we have no way of quantifying how much, if any, impact they are having on the price.

The underlying cause of most of the price increase, however, is that oil supply growth is challenged in the face of significant demand growth in developing countries. Much of this growth is occurring in countries where prices are subsidized to the consumer, thus distorting normal market signals. One of the primary reasons for the supply dynamic is that major energy companies such as ConocoPhillips have direct access to only 7 percent of the world's oil and natural gas resources, down from 85 percent in the 1960s. If U.S. policymakers want to increase supply availability, they should improve access to resources in the United States and encourage other nations to adopt similar policies.

5) **How much did your company invest last year in emerging energy technologies in North America and what types of technologies would that include?**

In 2007, ConocoPhillips invested about $150 million in emerging energy technologies in North America, including biofuels, coal-to-liquids, hydrogen and other technologies. However, it is important to understand that we are also making major investments in cutting edge technology in the production of oil and natural gas. Given the maturity of existing basins and restricted resource access, we have to develop increasingly complex unconventional oil and natural gas deposits that may have low recovery rates relative to conventional hydrocarbons and we have to move into deeper water. An enormous amount of new technology is needed to accommodate this shift and improve recovery rates. Refineries also need technology to enable them to process these unconventional crude oils and convert them to clean refined products. ConocoPhillips' overall technology spend between 2003 and 2007 was $1.3 billion in the United States alone.

6) In 2030, what percentage of global energy demand will be met by fossil fuels?

According to the International Energy Agency (IEA), fossil fuels will meet 82 percent of global oil demand in 2030. In their alternative scenario that assumes aggressive implementation of efficiency and alternative energy technology to stabilize carbon dioxide emissions at a level of 450 parts per million, they project that fossil fuels will still be needed to meet two-thirds of world energy demand. This projection demonstrates how difficult it will be to replace fossil fuels at the scale needed to completely satisfy the world's energy needs. That is why we believe it is important for government policy to promote energy efficiency and the development of all available energy sources, including fossil fuel sources.

7) Do you think that it is important as an energy security issue, to use more of the US reserves of oil and natural gas? What are the best policies to assure our energy independence?

Using more of our national oil and natural gas resources will improve the nation's energy security and provide employment opportunities for American workers. We can best ensure our energy security by diversifying our sources of energy, promoting energy efficiency and encouraging energy innovation, all in an environmentally responsible manner.

The Federal government is presently leasing only a small percentage of its holdings both onshore and offshore for oil and gas development. Of the 700 million acres of federal onshore energy lands, only 6 percent (44 million acres) is currently under lease for oil and gas development. In addition, the Federal government owns 1.7 billion acres of land in the Outer Continental Shelf and less than 3 percent is being leased for oil and gas production.

The onshore and offshore areas in the U.S. that are currently off limits to exploration and production are estimated to hold 80 billion barrels of recoverable oil and natural gas equivalent – enough to double current U.S. reserves. The U.S. also has considerable resources in unconventional oil and natural gas (e.g., shale oil). Additional domestic production from both sources would reduce our dependence on imports, increase our energy security and, by improving the global supply and demand balance, reduce upward pressure on global oil and natural gas prices.

Using more domestic resources would also improve the nation's economic security. The $11 trillion-dollar market value of these potential resources at current oil prices could be far better utilized at home to gainfully employ thousands of Americans, rather than be transferred to other countries to pay for oil imports.

The federal drilling moratoria on non-sensitive lands and the Outer Continental Shelf should be suspended and drilling allowed under prudent environmental oversight. Industry technology and operating practices have made quantum leaps in the years since these moratoria were enacted. Our national vulnerability no longer allows the luxury of ignoring so much energy potential.

Additional policies that are needed to improve U.S. energy security are:

- Promoting the building or expansion of critical energy infrastructure (e.g., refineries, pipelines, etc.) in the U.S., which is often stymied by federal, state and local permitting issues,
- Optimizing biofuels production, with policies that are technology and feedstock neutral, and that eliminate the tariff on imported ethanol,
- Encouraging alternative and unconventional sources,
- Improving energy efficiency
- Promoting nuclear energy development, and
- Encouraging technology innovation.

8) **What percentage of your stock is owned by pension plans and retirement accounts?**

About 6 percent of ConocoPhillips' shares are owned and managed directly by pension plans and retirement accounts. In addition, approximately 80 percent of ConocoPhillips' shares outstanding are held and managed by a large number of investment advisors on behalf of millions of Americans through their pension plans, retirement accounts, hedge funds, banks, trusts and other entities. These shares are held in a significant number of different funds that represent a large variety of investment styles and market exposures. While a large portion of this investment is tied to pension funds and retirement accounts, we are not able to determine the precise ownership.

9) **Do you support the use of coal-to-liquids as an alternative to traditional petroleum? If not, why not? As a follow up, wouldn't the use of coal-to-liquids significantly increase our domestic supply of fuel?**

We support the development of the coal-to-liquids (CTL) industry in the United States as a way to increase our energy security by supplementing current supplies of petroleum-derived transportation fuels, such as diesel, jet fuel, and gasoline. CTL technologies are technically viable, but they have yet to become commercially viable in the U.S. due to high project development costs.

The United States has vast coal resources and CTL could potentially make a moderate contribution to the country's fuel needs. However, the sheer size and scale of the investment and the development of a solution to reduce the carbon footprint (carbon capture and sequestration) will take time.

Currently the United States consumes approximately 14 million barrels per day of transportation fuel derived from petroleum crude oil, so it would take many years, perhaps several decades, before the CTL industry could develop enough commercial-scale plants to even partially offset our current consumption. We should also mention that coal gasification (the conversion of coal to methane or hydrogen), which is the front end of the CTL process, can be achieved at a much lower capital cost and is therefore likely to be commercialized sooner than coal-to-liquids.

It is important to note that coal, like oil, is a globally traded commodity that has also been experiencing strong price increases in the last year due to strong demand outside the United States. The price of Appalachian coal sold on the New York Mercantile Exchange more than tripled since the beginning of 2007.[1]

10) How much bio-fuel and ethanol do you think realistically can be substituted for traditional petroleum?

We believe that with the current and projected suite of available technologies and crop yields that a substitution of 10 percent (15-17 billion gallons per year or 1.0-1.1 million barrels per day) of transportation fuels by 2015 is feasible, but may not be prudent given the limitations of corn-based ethanol. Market penetrations beyond that level will require substantial breakthroughs in crop types and yields and conversion technologies. Penetration beyond 10 percent will also require relief of infrastructure constraints and technology development ranging from biomass gathering and transportation, conversion, biofuel distribution, blending and retailing to the vehicle fleet. Only about 3 percent of the present vehicle fleet can use fuel blends above 10 percent today.

The supply of corn-based ethanol may be impacted by other factors, such as weather conditions, adding to the uncertainty of supply as evidenced by this year's impact of the Midwest floods and poor growing conditions. There is risk even in "home grown" supplies. Supply diversity is the only real path to supply security.

11) Are you involved in developing production in Canada's oil sands or Western oil shale? Do you believe those alternatives will become more viable if the price of oil continues to rise?

ConocoPhillips has a leading land position in the Canadian Athabasca oil sands and is actively investing to produce this oil, and then transport it to the United States for processing at our U.S. refineries. We have access to over 15 billion barrels of net potential oil resources, and plans are in place to increase our net production to about 400,000 barrels per day over the next decade. In 2008 alone, we are spending $900 million in development capital on the Canadian oil sands.

The Canadian oil sands are a safe and secure source of energy, and we should ensure they are not excluded from the United States where they could provide about 20 percent of U.S. oil supply by 2020. Increases in the price of oil, together with technological improvements, will likely make additional volumes of resources commercially available. These resources may be drawn to other markets outside of North America if U.S. federal or state policies discourage their development. U.S. refineries are configured to process heavier, high sulfur crude oils, and with the decline in production of these types of crude oils (both in the U.S. and Latin America), the Canadian heavy crude oils are a very good fit to keep the U.S. crude supply secure and stable.

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[1] Price of NYMEX Columbia Appalachia coal was $39.75 per ton in January 2007 and the current price is $131.13 per ton

The processes required to produce Canadian oil sands and oil shale are energy-intensive, such that higher energy prices also increase the cost of producing these hydrocarbons. Thus, the increase in revenues is tempered by an increase in production costs in a higher price environment. The economics of these energy sources can be improved through advances in technology to improve recovery rates and lower the energy intensity. ConocoPhillips is spending significantly on technology to improve oil sands output and reduce energy usage.

The resource opportunity for oil shale is very large, with more than two-thirds of the world's oil shale located in the United States. A key challenge is that oil shale contains kerogen rather than oil. Kerogen is a partially decomposed algal material which requires high pressures and temperatures to complete the process of converting this matter into oil. This can be done in the ground (in situ) or at the surface, by mining and then retorting the material. The process of mining and retorting has been commercially proven in Brazil at a small-scale facility. The process is transferable, but has a number of environmental and scale-up issues which would need to be addressed before a development could be considered. At this time, no commercially viable in situ technologies have been developed. Development and production are likely to be higher cost than oil sands, which has had the benefit of many years of experience to reduce costs. ConocoPhillips holds a significant oil shale acreage position in Colorado's Piceance Basin and Utah's Uinta Basin.

12) The American Jobs Creation Act provides a tax credit of up to $1.00 per gallon for the sale and use of "agri-biodiesel" -- biodiesel from virgin agricultural products. The credit is $0.50 per gallon for biodiesel from recycled grease. In addition, the law provides an excise tax credit for biodiesel blends (i.e., biodiesel and conventional diesel). Producers are eligible for one credit or the other, but not both. The Energy Policy Act of 2005 extends these credits through 2008. Do you support making these credits permanent? Do you support increasing these credits?

We do not support increasing these credits and believe they should be available for a finite period of time to encourage innovation, provide a level playing field for all participants, and encourage any necessary infrastructure development. As Congress contemplates how to encourage continued growth of renewable fuels, care must be taken not to pre-select a favored feedstock and/or technology. Sound public policy should be feedstock and technology neutral. After a period of time, these biofuels should compete in the open market, and the market should determine which biofuels are sustainable.

13) Do you support suspending or reducing the number of "boutique fuel mixes" that each state mandates in order to reduce gas prices in the near future?

"Boutique fuel mixes" that are designated at the state or local level prevent the transfer of fuels from one region to another in the event of logistical or operational challenges. This causes shortages and price spikes. This problem is currently being exacerbated by the development of "boutique biofuels mixes." Congress could alleviate these problems by setting uniform national fuel requirements.

Another concern is the potential for overlapping fuel policies. For example, we hear that policies are being considered to add a national low-carbon fuel standard on top of the existing low-carbon renewable fuel standard. The overlap between these programs would further confound the overlap of state fuels programs. If the United States continues to overly constrain its production and supply systems, the result will likely be higher fuel costs and possibly even supply outages.

14) Do you believe that the Energy Independence and Security Act of 2007 went far enough to access US oil and natural gas resources?

The Energy Independence and Security Act of 2007 dealt with the demand side of the energy equation (for example, automobile fuel economy and energy efficiency in public buildings and lighting). It also focused on increasing the use of renewable fuels, which could not likely replace more than 10 percent of conventional fuels with current technologies and infrastructure. The bill did not allow for greater access to U.S. oil and gas resources; it did nothing to address the need for additional conventional energy production, which will supply most of oil and natural gas demand for the foreseeable future. The Federal government could improve our energy security significantly by removing impediments to these sources of potential energy.

15) Are you actively pursuing carbon sequestration and Enhanced Oil Recovery in your oil fields and has that work been successful? What more needs to be done in this area?

ConocoPhillips believes that development of carbon capture and storage (CCS) technology is essential as, according to projections, fossil fuels will continue to be a major source of energy for years to come. To help ensure that we have adequate supplies of energy, ConocoPhillips utilizes Enhanced Oil Recovery (EOR) techniques across a number of our operations and is actively pursuing potential applications of EOR across much of our oil and gas portfolio.

Carbon capture and storage

The company funds internal as well as university research in the United States, Canada, Australia, Norway and the United Kingdom that is investigating CCS technology and how it can be customized to meet our industry's needs and the needs of our specific sites.

We are in the planning phases for selecting several possible CCS sites in the United States and other countries. To facilitate this effort, we have allocated funding and personnel in the geosciences, reservoir engineering and other specialties to analyze seismic and engineering data to select the most appropriate sites and develop understanding of the basin containment mechanisms and optimum storage sizes.

ConocoPhillips is also engaged in a number of research projects with the U.S. Department of Energy (DOE). For example, we have commenced test drilling and will soon inject CO_2 into a major coal-bed methane formation in the San Juan Basin. We are a partner in the CO_2 Capture Project, a research consortium operated and funded by eight major energy companies, the European Union, Norway, and DOE, conducting more than $60 million in research projects to develop understanding of surface capture, subsurface storage applications, and methods to monitor and verify storage.

Widespread deployment of CCS will require national legislation that establishes a value for carbon emissions, supports technology research and development, provides incentives for early movers, and creates a regulatory and legal framework that provides the certainty necessary for long-term investment while letting market forces drive the most cost-efficient and environmentally effective CCS solutions. Our response to question #49 provides greater detail about what needs to be done in this area.

Enhanced oil recovery

Increasing the amount of hydrocarbons extracted from our existing fields using EOR is a primary focus for ConocoPhillips, especially given the resource access constraints we face both domestically and globally. The company currently operates and oversees some of the largest gas-based EOR processes in the world on the North Slope of Alaska, including projects in the Prudhoe Bay, Kuparuk, Point McIntyre, Alpine and Tarn oil fields. The projects are currently delivering many tens of thousands of barrels of oil per day into the market. Ultimately, the projects will yield a combined total of nearly a billion barrels of oil over their full life cycle, each of which is several decades long. We also have EOR projects in the Permian Basin, San Juan Basin (New Mexico/Colorado), Wind River Basin (Wyoming), Williston Basin (Montana and North Dakota), Gulf of Mexico and the North Sea. Higher oil prices have enabled us to increase the application of EOR, and we are looking for opportunities to use EOR to re-activate previously shut-in wells that had passed their economic production limit. The Permian Basin in West Texas is a place where we are having good success with this type of activity.

By definition, the oil recovered by EOR processes is that which is left behind by conventional methods. This requires significant capital investment for additional infrastructure required, which could include additional wells, pipelines, high pressure compression facilities, metering etc. Consequently, EOR projects are more costly on a per barrel basis than conventional projects. Maintenance of the EOR Tax Credit program is important to our continued piloting and development efforts.

16) What is a ballpark figure of how much your company pays in taxes each year?

ConocoPhillips paid an estimated $14 billion in taxes during 2007, which was greater than our net income. This does not even include royalties and lease bonuses the company also pays to governments. When you take all these other forms of government payment into account, our effective tax rates are much higher. For example, our incremental fiscal-take rate[2] in Alaska is about 90 percent at recent oil prices.

17) A couple of you mentioned the National Petroleum Council report "Facing the Hard Truths about Energy" do any of you disagree with the findings of that report?

The National Petroleum Council (NPC) conducted a comprehensive study considering the future of oil and gas to 2030 in the context of the global energy system. The study included an integrated view of supply, demand, technology and geopolitics, and of policy options viewed through economic, security, and environmental lenses. The study also included more than 350 participants from diverse backgrounds and organizations and a dialogue with more than 1,000 persons and groups actively involved in energy. We agree with the NPC's conclusion that given the massive scale of the global energy system and long lead-times necessary to make material changes, actions must be initiated now and sustained over the long term. We further agree that over the next 25 years, coal, oil and natural gas will remain indispensable to meeting total projected energy demand growth and that expansion of all economic energy sources will be required, including coal, nuclear, biomass, other renewables and unconventional oil and natural gas resources.

18) Several of you mentioned the increasing cost of materials, difficulty in finding labor and specifically difficulty in finding engineers and scientists in oil and gas development. What policies do you think would help get the materials and people that you need?

One of the more important predictors for the future supply of potential employees in the oil and natural gas industry is the number of students earning university degrees in petroleum engineering and geosciences. Enrollment in these programs has dropped by about 75 percent over the last quarter century.

While the United States has traditionally been a leader in technology, our lead is slipping. The chart on the next page shows that the number of engineering degrees earned in the U.S. has leveled off, while it is growing rapidly in China.

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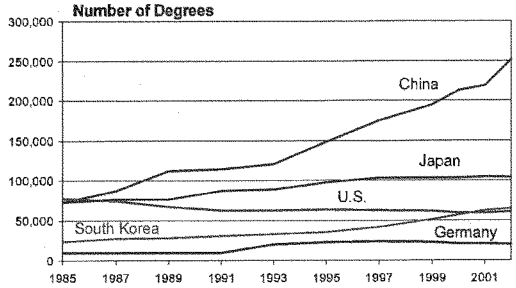
[2] The amount of an incremental dollar in revenue that is paid to the government (state and federal) in the form of production taxes, royalties, federal and state income taxes and any other taxes; incremental rate in Alaska is 90% at $115/bbl oil price

Engineering Degrees Earned



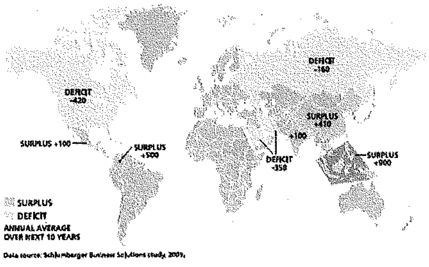
Source: National Science Foundation, Science & Engineering Indicators 2006

A national commitment to support technical education is needed. We need better curriculum in math and sciences, as well as energy, in Elementary School through High School programs. We need more college students majoring in engineering, geology, geophysics and the other technical disciplines. We also need better secondary education to prepare them. A technical workforce is needed for the development of unconventional and alternative supplies as well as for developing conventional hydrocarbons. Specific policies that would support technical education include:

- Provide scholarships to those seeking engineering and other technical degrees, both undergraduate and graduate,
- Increase research funding at universities and support for technical schools, and
- Encourage the development of curriculum focusing on math, science and energy for kindergarten through grade 12.

We also need to be able to access technical talent from other parts of the world. The graphic on the next page indicates that Asia has a surplus of graduates with petrotechnical skills, while North America has a deficit. Our policies need to allow the immigration of trained professionals in energy and technical fields. Government policy can support the U.S. obtaining the technical talent it needs by increasing immigration quotas for trained professionals in energy and technical fields.

Technical Graduate Imbalance



Source: National Petroleum Council, Global Oil and Gas Study, 2007

We also believe that relaxation of immigration policy directed specifically towards craft labor such as boilermakers, insulators, equipment operators, electricians, pipe fitters, sheet metal workers, etc., will immediately help reduce costs.

19) Is there something in the manufacturing sector that we need to do to help insure that you get the supplies that you need?

There are near-term as well as long-term actions that can be undertaken in order to help U.S. manufacturing and to relieve some of the supply constraints facing the industry.

A near-term action that would help is streamlined permitting and efficient regulatory compliance processes for constructing or expanding energy infrastructure, which would enable earlier procurement of long-lead time materials.

With respect to long-term solutions, we would recommend completing an "energy infrastructure study" recommended by the 2007 National Petroleum Council (NPC) study "Facing the Hard Truths about Energy." This study would help evaluate the global requirements for infrastructure needed to meet our energy demand. The findings can then be used as an input to a National Association of Manufactures (NAM) or another agency/organization for what it would take to manufacture the infrastructure components required by the energy industry. Such a study would benefit our procurement planning efforts because of an improved visibility of aggregated demand.

Another long-term solution would be for the federal government to fund and integrate next generation science, engineering and productivity-enhancing technologies in manufacturing processes. Major technologies of promise could include semiconductors, materials science, network communications, biotechnology and nano-technology. Initial funding of basic science by the government followed by technology commercialization investment in applied R&D by the private sector would be very helpful.

Another long-term solution would be to lower the cost of manufacturing in the United States. Higher energy costs contribute to the higher costs of manufacturing, although they are probably not the primary cause for most industries. Enacting a policy that helps expand domestic production and distribution of clean-burning natural gas will substantially reduce the cost in manufacturing sectors.

20) The International Energy Agency estimates that $22 trillion – in new energy investments will be needed by 2030. Where would that money come from?

Most of that money will come from energy companies reinvesting their earnings. Thus, it is important to avoid tax or other policies that reduce companies' ability to invest in new energy supplies. Global capital markets can supply the needed capital if restraints or impediments, such as restricted resource access or high tax rates, are not placed on the investments and returns.

21) What would be required to get biofuels to a commercial scale that they could replace oil in the United States?

It is unlikely that biofuels will be sufficient in scale to replace petroleum as the primary transportation fuel unless transportation fuel demand is dramatically reduced in ways that are not yet possible, for example by moving away from the internal combustion engine. The most optimistic study[3] showed the potential of a 30 percent replacement of transportation fuels. Biofuels should be seen as an extender to petroleum liquid fuels, not a replacement.

It would also be helpful if the U.S. could better compete for imports of biofuels. We believe that our nation should eliminate the current 54-cent-per-gallon tariff on imported ethanol. If the nation is concerned about reducing fuel costs and carbon emissions, policies and taxes that discourage lower-cost and less carbon-intensive imports, such as sugar-based ethanol from Brazil, are counter-productive.

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[3] USDA/DOE, "Biomass as a feedstock for Biomass and Bioproducts Industry: The Technical Feasibility of a Billion Ton Annual Supply"

22) In your testimony, several of you point to speculation as a contributing cause of high crude oil prices. I have introduced legislation, the Prevent Unfair Manipulation of Prices (PUMP) Act (HR 594), which would improve oversight of "dark markets" which are currently unregulated by the Commodity Futures Trading Commission. In our December 2007 Oversight and Investigation Subcommittee hearing, we heard testimony that this could reduce the cost of oil by $30 a barrel. Do you believe that speculation in the market is driving up the price of oil? Would you support this legislation?

We believe some investors are diversifying financial risks in their stock and bond portfolios by investing in crude oil and other commodity futures but we have no way of quantifying how much, if any, impact they are having on the price.

We support legislation that ensures regulatory bodies have the resources and information to execute their responsibilities in a way that does not impair the ability of the market to function in a free and open manner. In other words, we support legislation that increases transparency as long as it maintains liquidity and passes a cost/benefit test.

However, the underlying cause of most of the price increase is that oil supply growth is challenged in the face of significant demand growth in developing countries. One of the primary reasons for this dynamic is that major energy companies such as ConocoPhillips have direct access to only 7 percent of the world's oil and natural gas resources, down from 85 percent in the 1960s. If U.S. policymakers want to increase supply availability and decrease dependence on foreign sources of energy, they should improve access to resources in the United States.

23) What is the average number of barrels of oil your companies trade each day on NYMEX? On the InterContinental Exchange?

ConocoPhillips is a commercial participant in the crude futures market. We do not believe our futures market transactions have any net effect on the price of oil. Our participation in the futures market is typically intended to offset the price risk associated with physical purchase and sale of crude oil required to run our refineries and supply consumers.

ConocoPhillips measured the number of New York Mercantile Exchange (NYMEX) West Texas Intermediate (WTI), and IntercontinentalExchange (ICE) WTI and Brent contracts transacted by the Company between March 1, 2008 and May 30, 2008. An average of approximately 2.0 million barrels per day was purchased and 2.0 million barrels per day was sold in NYMEX WTI futures contracts during that period. An average of approximately 1.1 million barrels per day was purchased and 1.2 million barrels per day were sold in ICE WTI and Brent contracts during that period. For comparison purposes, a total of 527.0 million barrels of WTI were traded by all market participants in the NYMEX WTI contract on May 30, 2008. Likewise, all participants traded 256.7 million barrels of WTI on ICE on May 30, 2008.

We purchase NYMEX WTI futures and exchange those contracts for physically-delivered crude oil at Cushing, Oklahoma. That crude oil is either transported directly to our refineries or traded with other counterparties in exchange for the grades of crude oil (West Texas Sour, Mars, Heavy Louisiana Sweet, Light Louisiana Sweet, San Joaquin Valley Heavy Sour, Canadian import crude oils and others) that better fit our refinery requirements. We also use the futures contracts to convert fixed price risk in our physical crude oil purchases and sales to ratable market average pricing (such as in the case of fixed pricing associated with cargoes of crude oil). Futures contracts are also useful in managing the timing and location risks inherent in acquisition and transportation of crude oil, as well as the commodity price spread risks between various grades of crude oils and between crude oil and refined products.

24) During the April 1, 2008 hearing, you each spent most of your time complaining about taxes, specifically that the Renewable Energy and Energy Conservation Tax Act (H.R. 5351) passed by the House would repeal $18 billion over ten years in subsidies to your companies. Several times during the hearing, you also said that your companies do not support mandates and subsidies for renewable fuels. Over the next ten years, your companies are expected to make $14.6 trillion. H.R. 5351 would only account for approximately one tenth of one percent of your gross income! How can you insist on retaining these subsidies and tax breaks for your companies while opposing assistance for renewable energy?

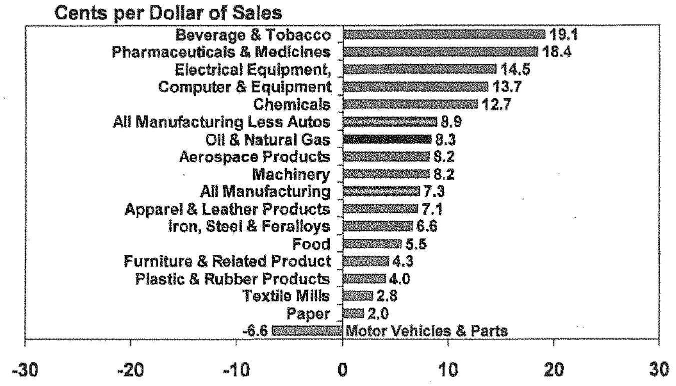
First, we have not sought to verify your forecast of the selected companies' earnings given all the uncertainties with the commodity price outlook, volume growth and industry cost structure but believe that you have not appropriately characterized the industry's profitability. The size of our profits reflects the scale of our companies and industry but they are not necessarily a good reflection of financial performance. Despite the higher crude prices in recent years, the oil and natural gas industry's earnings as a percentage of sales and returns on investments are in line with other industries as described below.

Profit margins, or earnings per dollar of sales (measured as net income divided by revenues), provide one useful way to compare financial performance among industries of all sizes. The latest published data for 2007 show the oil and natural gas industry earned 8.3 cents for every dollar of sales compared to 7.3 cents for all U.S. manufacturing and 8.9 cents for U.S. manufacturing, excluding the financially challenged auto industry (see first figure on the next page).

The chart on return on investment (see second figure on the next page), based on U.S. Department of Energy data, shows the returns for the oil and natural gas industry are currently comparable to average returns for the S&P industrials, after lagging those returns for many years.

2007 Earnings by Industry

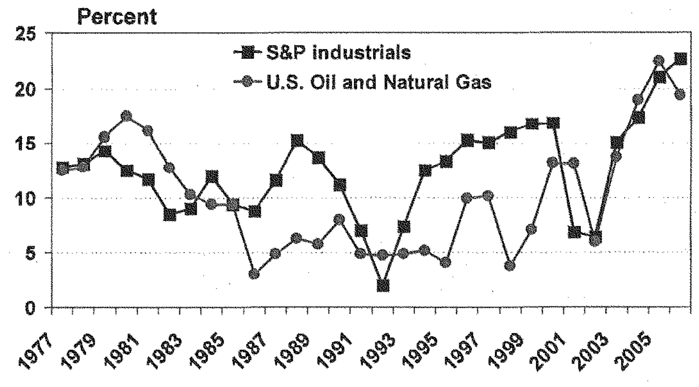
Net Income / Sales



Source: Based on company filings with the federal government as reported by U.S. Census Bureau and Oil Daily

Industry Return on Investment

Net Income / Net Investment in Place



Source: U.S. Department of Energy, Energy Information Administration, Performance Profiles of Major Energy Producers, various issues and 2006 S&P figure compiled by PWC from Compustat data

The proposal to repeal the Section 199 domestic manufacturing deduction for the five largest oil companies would discriminatorily deny the benefit of a tax deduction that is available to every other industry and other large oil companies. In our case, this provision of the tax code encourages more domestic oil and natural gas production, which increases our energy security and helps preserve U.S. jobs.

The cost for exploration and production of oil and natural gas in the U.S. is among the highest in the world due to the maturity of U.S. basins and the need to move into deep water in the Gulf of Mexico. The Section 199 tax deduction will help domestic oil and gas production compete with lower-cost international opportunities.

The foreign tax credit eliminates double taxation for every multinational company subject to U.S. tax laws. The proposed modifications to this credit would further hamper our ability to compete in global markets against foreign oil companies.

Major oil companies are already heavily taxed. In a recent survey of 80 diverse American companies, ConocoPhillips' effective tax rate between 2004 and 2006 of 43.6 percent was the highest, about 14 percent higher than the average. ConocoPhillips paid an estimated $14 billion in total taxes during 2007, which was greater than our net income. Income taxes paid by domestic energy producers have already increased by 519 percent between 2002 and 2006.[4] Income taxes are only one of the ways we contribute to government revenues. We also pay royalties, production and excise taxes, and lease bonuses, the latter of which are paid whether you discover hydrocarbons or not. When you take all these other forms of government payment into account, our effective tax rates are much higher. For example, our incremental fiscal-take rate[5] in Alaska is about 90 percent at recent oil prices.

Over the last four years the state of Alaska has changed their tax structure to significantly increase taxes on the oil and gas industry three different times. This not only increases the costs associated with oil and gas production and developments, but also adds uncertainty to the predictability of the fiscal structure in Alaska going forward. These tax increases have had and will continue to have a chilling impact on investment in Alaska. Some major projects have been cancelled or deferred in late 2007 and early 2008, due at least in part to tax impacts.

We support appropriate incentives, including tax incentives, to encourage innovation in renewable energy and encourage any necessary infrastructure development. For example, we believe that Congress should extend the investment tax credits for renewable power sources by five years at a time to help provide the financial certainty needed for investment. However, we believe that development of these renewable energy sources benefits the public at large and should be paid for with public funding, not by imposing discriminatory tax provisions on five American companies, as is being considered. This would reduce our ability to replenish conventional oil and natural gas supplies, and to develop alternative energy sources.

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[4] U.S. Department of Energy, Energy Information Administration, "Performance Profiles of Major Energy Producers 2006," Table B12 ($14.6 billion in 2002 to $90.4 billion in 2006)

[5] The amount of an incremental dollar in revenue that is paid to the government (state and federal) in the form of production taxes, royalties, federal and state income taxes and any other taxes; incremental rate in Alaska is 90% at $115/bbl oil price

As Congress contemplates how to encourage continued growth of renewable fuels, care must be taken not to pre-select a favored feedstock and/or technology. Sound public policy should be feedstock and technology neutral. After a period of time, these renewable fuels should compete in the open market, and the market should determine which renewable fuels are sustainable.

25) At the American Society of Newspaper Editors Convention on April 14, 2005, the President said, "I will tell you, with $55 [a barrel] oil we don't need incentives to oil and gas companies to explore. There are plenty of incentives. What we need is to put a strategy in place that will help this country over time become less dependent. It's really important. It's an important part of our economic security, and it's an important part of our national security." Today, crude oil prices are double the President's example! Do you agree with President Bush that oil and gas companies do not need incentives to explore when oil is more than $55 a barrel? Do you agree with President Bush that we should instead be investing in renewable energy that will help this country become less dependent on oil?

Industry drilling and service costs tend to follow oil prices with a two-year lag. Thus, if it is uneconomic to explore at a $55 per barrel price and cost structure, it may well be uneconomic to explore at much higher prices given the accompanying increase in cost structure.

Additionally, incentives for domestic oil and gas production have traditionally targeted those areas or resources that, but for incentives, would not receive investment. Because so much of the lands with greatest energy potential owned by the government are either specifically or in practice not accessible, policies have been adopted to encourage investment in less economically-robust areas. It is a means to induce explorers to invest in areas that they might not otherwise explore because the more economic areas are off-limits.

We are concerned about certain proposed discriminatory tax policies that would target just a few companies for tax increases. The proposal to repeal the Section 199 domestic manufacturing deduction for the five largest oil companies would discriminatorily deny the benefit of a tax deduction that is available to every other industry and other large oil companies. In our case, this provision of the tax code encourages more domestic oil and natural gas production, which increases our energy security and helps preserve U.S. jobs.

The cost for exploration and production of oil and natural gas in the U.S. is among the highest in the world due to the maturity of U.S. basins and the need to move into deep water in the Gulf of Mexico. The Section 199 tax deduction helps domestic oil and gas production compete with lower-cost international opportunities.

The foreign tax credit eliminates double taxation for every multinational company subject to U.S. tax laws. The loss of this credit, as has been proposed, would further hamper our ability to compete against foreign oil companies.

Major oil companies are already heavily taxed. In a recent survey of 80 diverse American companies, ConocoPhillips' effective tax rate between 2004 and 2006 of 43.6 percent was the highest, about 14 percent higher than the average. ConocoPhillips paid an estimated $14 billion in taxes during 2007, which was greater than our net income. When you include other forms of government payment such as royalties and lease bonuses, our effective tax rates are much higher. For example, our incremental fiscal-take rate[6] in Alaska is about 90 percent at recent oil prices.

We believe that the United States should be encouraging investment in renewable and alternative fuels. We support appropriate incentives, including tax incentives, to encourage innovation in renewable energy and encourage any necessary infrastructure development. For example, we believe that Congress should extend the investment tax credits for renewable power sources by five years at a time to help provide the financial certainty needed for investment. However, we believe that development of these renewable energy sources benefits the public at large and should be paid for with public funding, not by imposing discriminatory tax provisions on five American companies, as is being considered. This would reduce our ability to replenish conventional oil and natural gas supplies, and to develop alternative energy sources.

As Congress contemplates how to encourage continued growth of renewable fuels, care must be taken not to pre-select a favored feedstock and/or technology. Sound public policy should be feedstock and technology neutral. After a period of time, these renewable fuels should compete in the open market, and the market should determine which renewable fuels are sustainable.

26) I have attached internal memos from Chevron, Texaco, and Mobil. The Chevron memo quotes a "senior energy analyst at the recent API convention," stating "if the US petroleum industry doesn't reduce its refining capacity it will never see any substantial increase" in profits. The Texaco memo complains that "supply significantly exceeds demand" leading to "very poor refinery margins and very poor refinery financial results." The Mobil memo advocates keeping a smaller refiner, Powerine, from reopening, stating that a "full court press is warranted in this case." From 1995 to 2002, more than 30 refineries have been closed in the United States. Have any of your companies applied for permits to build new refineries? If yes, how long did it take to obtain the necessary permits? In July 2007, gas prices increased 30 cents overnight in Escanaba, Michigan. There were no supply disruptions or other major events that would influence the price this significantly. Is there any logical explanation why prices would increase 30 cents in that short of time? On May 23, 2007, the U.S. House of Representatives passed H.R. 1252, the Federal Energy Price Gouging Prevention Act by an overwhelming vote of 284 to 141. Please explain why this legislation is not needed, given the significant price increases consumers continue to face.

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[6] The amount of an incremental dollar in revenue that is paid to the government (state and federal) in the form of production taxes, royalties, federal and state income taxes and any other taxes; incremental rate in Alaska is 90% at $115/bbl oil price

New refineries have not been built in the United States because building new refineries would cost considerably more than expanding existing refineries, and would face much greater permitting challenges. Thus, the industry has focused on incremental expansions of existing refineries. In fact, continuous expansions and improved efficiency have enabled the U.S. refining industry to increase crude runs nearly 30 percent since 1983, despite closures of a number of small refineries. The number of operable refineries in the United States fell from 319 in 1980 to 149 in 2007.

Let me address why the number, but not the capacity, of refineries has decreased. According to the FTC, the closures typically involved small, relatively unsophisticated refineries.[7] Between 1973 and 1981, federal government incentives enabled companies to own and profitably operate these small and often inefficient refineries. However, these refineries could not survive after the elimination of these incentives in 1981 as well as by the large capital expenditures that were required to meet government-mandated product specifications (such as clean fuels) and emissions reductions. The lack of economies of scale significantly disadvantaged the small refiner. The average size of the current U.S. refinery is about 125,000 barrels per day, and some of the new global refineries being built are being sized at about 400,000 barrels per day, and when it is completed there will be a refining complex in India with a capacity of 1.2 million barrels per day.

ConocoPhillips is investing in our refineries. In 2008 alone, we plan to invest $2.8 billion in our global refining, marketing and transportation operations, with 74 percent of that invested in the United States. Over the next five years, we plan to invest $7.0 – $7.5 billion in our base refining, marketing and transportation business and an additional $6.5 – $7.0 billion on refinery projects that increase crude oil refining capacity, raise clean product yields or enhance the ability to utilize low-cost (and thus more difficult to refine) crude supply.

Even when the considerable economic hurdles for major expansions can be overcome, we are finding it extremely difficult to obtain permits for expansions in the United States. For example, ConocoPhillips applied in May 2006 for a permit to expand the Wood River refinery (a 50 percent joint venture with EnCana) in Illinois, and still does not have a final permit. At our refinery in Wilmington, California, local permit challenges and litigation have threatened an ultra-low-sulfur diesel fuel project since 2004. An expansion at our Rodeo refinery near San Francisco took 28 months to permit. U.S. refineries need to compete against very large and efficient refineries being built around the world today. We will not be able to compete successfully if we cannot complete our expansions and improvements in a timely fashion.

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[7] U.S. Federal Trade Commission, Bureau of Economics, "The Petroleum Industry: Mergers, Structural Change, and Antitrust Enforcement," August 2004, page 7

We are not familiar with the specific circumstances associated with Escanaba, Michigan but industry data indicates that there were a number of disruptions to refining output in the MidContinent region in July 2007 that temporarily increased gasoline prices in the region. According to a trade publication, BP's Whiting, Indiana refinery had a crude pipeline shut down, Coffeyville Resources' Kansas refinery flooded, Husky's Lima, Ohio refinery had a fire and power loss and Sunoco's Tulsa, Oklahoma refinery had a number of units down during this period. The overall loss of gasoline supply was estimated at 110,000 barrels per day.

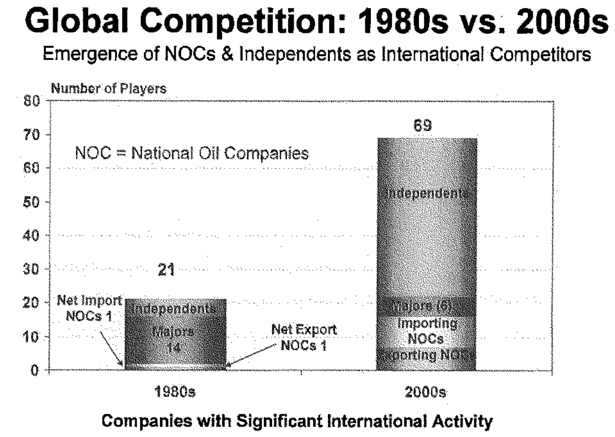
ConocoPhillips does not condone or tolerate taking advantage of consumers under any circumstance. However, we do not support price gouging legislation because of the potential to exacerbate shortages during supply disruptions. Anti price-gouging legislation is a form of price control, similar to that which resulted in long lines at the pumps in the 1970s. Price gouging legislation, just like price controls, does nothing to increase supply, and nothing to decrease demand. Rather, it removes the price signal to consumers to conserve and to producers and importers to bring forth additional supplies during a supply disruption. Furthermore, "price gouging" is difficult to define. This creates legal uncertainty and could produce adverse unintended consequences if suppliers decide not to sell a product in a tight supply situation rather than face potential protracted litigation over pricing. Price caps will very likely decrease supply and increase demand – exactly the opposite of what is needed to bring supply and demand into balance.

Markets are working. Repeated investigations, including those associated with Hurricanes Katrina and Rita, have consistently found that petroleum markets operate competitively and without manipulation. The industry's supply response to the dual hurricanes in 2005 that temporarily shut down nearly 30 percent of total U.S. refining capacity was so effective that the average retail gasoline price returned to pre-hurricane levels within one month of the landfall of Hurricane Rita. It is doubtful that such a supply response would have occurred if price-gouging legislation was in effect that interfered with price signals.

27) **In May 2004, the U.S. General Accounting Office released its report, "Effects of Mergers and Market Concentration in the U.S. Petroleum Industry." In this report, GAO found that over 2,600 mergers have occurred in the U.S. petroleum industry since 1990. The GAO also pointed to economic literature that suggests that firms sometimes merged to enhance their ability to control prices. Each of your companies today is the result of significant mergers in the industry. Do you see any more mergers taking place?**

One of the primary reasons for the merger between Conoco Inc. and Phillips Petroleum Company was a response to rising constraints on resource access both in the U.S. and abroad and the growing competitiveness of national oil companies around the world. These trends forced us to undertake increasingly large and complex projects that some national oil companies did not have the financial strength, skills or technology to undertake on their own. Only large companies with substantial financial capacity and technical resources can effectively develop these mega projects, while sufficiently diversifying the number of projects and geographies to manage the risk. If these conditions persist, it is possible companies will need to become larger and more diverse in order to compete.

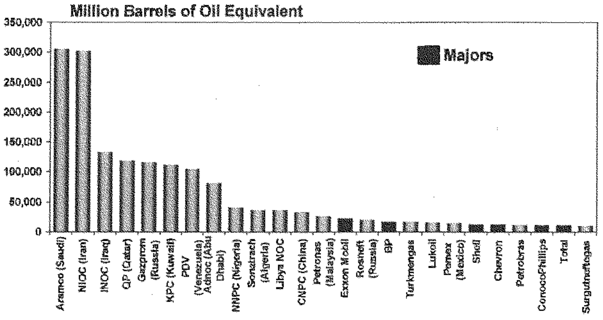
We also believe that it is implausible that mergers have enabled oil and gas firms to control prices. Global competition is much greater today than it was before these mergers, even though there are fewer major integrated oil companies. In the 1980s, for example, there were 21 active global competitors dominated by publicly traded majors. In the 2000s, there are more than 3 times the number of global competitors and the majors constitute a minority (see figure below).



Source: PFC Energy & Internal Company data

Despite these mergers, the integrated major oil companies have a small market share of the world's oil and gas reserves as shown in the figure on the next page. Today, the top six major integrated oil companies together hold only 4.5 percent of the world's oil and gas reserves.

Top 25 Oil, NGL and Natural Gas Reserves

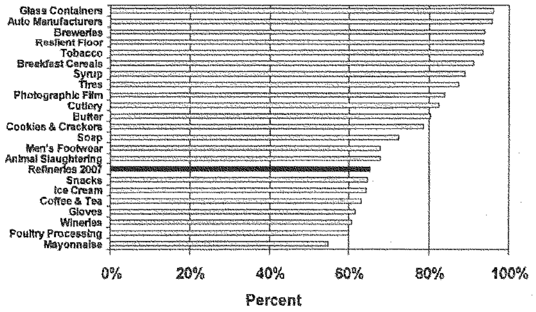


Source: Energy Intelligence Group, Ranking the World's Oil Companies 2008

Turning to the U.S. refining industry, the Federal Trade Commission (FTC) concluded that "the refining industry remains relatively unconcentrated" and that "no refiner has a substantial share of crude oil distillation refining capacity, either nationally or regionally."[8] In addition, the refining industry is not very concentrated relative to many other industries in the U.S. The chart below shows that the market share of the eight largest firms for refining is much lower than for many other industries in the United States.

Eight Firm Concentration (2002)

Percent of Market Composed of the Eight Largest Firms



Source: Energy Information Administration for Refineries 2007, U.S. Department of Commerce for all others

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[8] Federal Trade Commission, "Investigation of Gasoline Price Manipulation and Post-Katrina Gasoline Price Increases," Spring 2006, page 16

We would also note that the FTC criticized the 2004 GAO study referred to for, "(1) methodological mistakes that make the Report's quantitative analysis wholly unreliable, (2) critical factual assumptions that are both unstated and unjustified, and (3) conclusions that lack any quantitative foundation."[9] The study did not take into account the numerous other factors besides mergers that caused gasoline prices to increase during the period studied (e.g., supply disruptions, seasonality, boutique fuels, higher cost of manufacturing clean fuels).

We believe that the efficiency improvements resulting from the mergers have probably lowered consumer prices relative to what they would have been otherwise. In my written testimony, I addressed in detail how the merger of Conoco Inc. and Phillips Petroleum Company has benefited consumers by reducing costs, improving the efficiency of our business, and increasing supplies of petroleum products for American consumers. In fact, we estimated cumulative cost and efficiency savings of approximately $1.9 billion in 2004 resulting from this merger.

28) In your testimony, almost all of you mention "more domestic drilling" as your top solution to high energy prices. What assurance can you provide that oil and gas from the Arctic National Wildlife Refuge (ANWR), the Outer Continental Shelf (OCS), or other domestic sources would stay in the United States? What is your response to economists that tell us that the oil and gas will likely go to higher priced markets in Japan and elsewhere?

The price for crude oil is determined by the extremely active global oil market, which includes multiple buyers and sellers and ample liquidity. Since every country around the world is essentially paying the same price for crude, the additional shipping cost provides a substantial disincentive for domestic crude production to leave the U.S. Instead, this additional production is likely to replace oil imports.

The situation for natural gas is different today because U.S. natural gas prices are lower than the oil-indexed natural gas prices being charged in Asia and Continental Europe. It is true that LNG has been bid away from U.S. markets by other countries that have shown a willingness to pay higher prices than exist in the U.S. at any given time. However, the U.S. generally does not export natural gas, with the exception of a small volume of LNG exports from Alaska and some small exports to Mexico and Canada via pipeline interconnects. Furthermore, natural gas cannot be exported without the permission of the U.S. government.

We have looked at options to developing the gas resources on the Alaska North Slope and have concluded that the best option is to construct a pipeline to North American markets. ConocoPhillips and BP recently announced a decision to advance development of the Denali pipeline project.

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[9] Federal Trade Commission letter to GAO, "Energy Markets: Effects of Mergers and Market Concentration in the U.S. Petroleum Industry," May 2004, Appendix IV, page 153

29) **In May 2006, the Energy and Commerce Committee held a hearing on gas prices, and we discussed the crack spread, or the difference between a barrel of crude oil and the refined product. At this hearing, the average crack spread for a refinery in 2006 was estimated to be about $20 to $30 a barrel by Howard Gruenspect, the Deputy Administrator at the Energy Information Administration. Mr. Gruenspect testified that a crack spread of $8 or $9 is sufficient to cover refining expenses and provide a reasonable profit to the facility. What is your current crack spread at the refineries your companies operate? Why have your companies scaled back their refinery expansion plans to keep crack spreads high?**

The Deputy Administrator appeared to be referring to a gasoline crack, which is the difference between the spot or wholesale gasoline price and the crude price. A gasoline crack does not deduct any refinery costs. Thus, it is an increasingly poor indicator of actual refining margins during periods like we are in now when costs are rising rapidly. For example, the Nelson-Farrar composite index of U.S. refinery operating costs increased by 54 percent since 2002.[10]

In addition, the usual simple indicator of refinery profitability is not a gasoline crack spread as is being discussed but rather a 3:2:1 crack spread, which assumes a refinery takes in 3 parts of crude and produces 2 parts of gasoline and 1 part distillate (diesel fuel and heating oil). But even that indicator can grossly overstate a specific refinery's profitability because refineries produce varying amounts of co-products other than gasoline and distillate that are priced below the price of crude oil. The refinery can only run profitably when the gasoline and diesel prices cover the losses incurred from selling those products that are priced below the cost of crude feedstock.

A gasoline crack of $8 - $9 per barrel will normally keep complex refineries running but it is not sufficient to cover capital over a stay-in-business level. In a period of tight refining capacity, when expansion is needed, you would expect the gasoline crack to rise above this level to incent capital investment.

While there were brief periods of elevated gasoline crack spreads during 2006 and 2007, the average gasoline crack spread (Gulf Coast spot gasoline price minus West Texas Intermediate or WTI crude oil price) for 2006 was about $10.60 per barrel. As a result of strong oil demand growth in developing countries, global refining capacity utilization was very tight and the U.S. found it more difficult to attract imports. Since then the supply / demand balance for gasoline has loosened considerably due in part to:

- A decline in U.S. gasoline demand caused by the higher gasoline price levels (in turn caused by higher crude oil prices) and the slowdown in the U.S. economy,
- Refinery capacity expansions,
- The restoration of domestic refining capacity that was disrupted last year, and
- The increased use of ethanol in gasoline.

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[10] Oil and Gas Journal data base, "Nelson-Farrar refinery operating index," monthly as of February 2008

Evidence for the restoration of the balance in gasoline markets is the fact that gasoline price increases are not keeping pace with crude oil price increases this year. On the week of May 30, 2008 versus May 30, 2007, the crude price doubled but spot gasoline prices only went up by 45 percent. The average gasoline crack spread year-to-date in 2008 has been about $4.40 per barrel, which is significantly below the $8 - $9 per barrel to which Mr. Gruenspect referred. The fundamentals for gasoline are weakening in the United States and Europe. The surplus of gasoline is likely to grow over time as the U.S. ramps up ethanol use towards the 36 billion gallon mandate and vehicle fuel efficiency increases as required by the Energy Independence and Security Act of 2007.

The refining industry is a highly cyclical industry as are other capital-intensive industries. The few years of elevated refining margins that were high enough to justify new capacity initiated a round of refinery expansions. The International Energy Agency estimates that 10.6 million barrels per day of global refining capacity is being added between 2007 and 2012. Half of the additions are from incremental expansions in the United States and Asia and half are from new refineries being built in the Middle East and developing Asian nations. In addition to the 1.1 million barrels per day of expansions in distillation capacity planned in the United States by 2012, there are also large-scale upgrading capacity additions that will process increasing amounts of Canadian heavy, sour crude oil, and increase yields of clean-fuels products. [11]

Certain projects have been scaled back largely because of:

- The lack of projected gasoline demand growth due to government policies that increased ethanol usage and fuel efficiency standards for new vehicles,
- The growing surplus of gasoline supplies in the U.S. and Europe,
- Falling refining margins,
- Rapidly rising capital costs of construction, and
- Rapidly rising operating costs.

If new gasoline production cannot be placed in the market, refineries will not be able to operate at design capacity.

We are continuing to invest in our refineries. In 2008 alone, we plan to invest $2.8 billion in our global refining, marketing and transportation operations. Of that amount, 74 percent will be invested in the United States and 69 percent will be invested in refining.

Over the next five years (2008-2012), we plan to invest $7.0 - $7.5 billion in our base refining, marketing and transportation business and $6.5 - $7.0 billion on strategic investments, which are primarily refinery projects that increase crude capacity, clean product yields or the ability to utilize low-cost crude supply.

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[11] International Energy Agency, "Medium-Term Oil Market Report," July 2007, pages 54 and 60

We are finding it extremely difficult to obtain permits for expansions in the United States. For example, we applied in May 2006 for a permit to expand the Wood River refinery (a 50 percent joint venture with EnCana) in Illinois, and still do not have a final permit. At our refinery in Wilmington, California, local permit challenges and litigation have threatened an ultra-low-sulfur diesel fuel project since 2004. An expansion at our Rodeo refinery near San Francisco took 28 months to permit. Where infrastructure is clearly needed to serve the national interest, Congress should expedite federal and state permitting processes to ensure a balance between federal, state and local and special interests.

30) Please provide a list of oil and gas leases currently in the possession of your company and its subsidiaries, and give a status report as to the state of the production of each of these leases.

ConocoPhillips held 3,723 federal leases in the United States at year-end 2007, including offshore and onshore leases in the Lower 48 states and Alaska. Of these federal leases, 2,582 or 69 percent had already been developed by year-end 2007. While 1,141 or 31 percent were undeveloped, subtracting leases currently suspended due to environmental or other restrictions reduced the percentage of undeveloped leases to 26 percent. While we were not able to provide the status of each of the 3,723 individual leases we hold in the timeframe allotted, we believe the information we have provided addresses the substance of the question.

There will always be a proportion of leases that are undeveloped. They represent "working inventory," since development typically requires a number of years from when a lease is awarded, particularly offshore or in remote onshore areas. For example, the Gulf of Mexico deep water trend is characterized by remote prospect locations, complex geology, massive facility size and potentially hostile weather – all of which contribute to multi-billion-dollar capital needs. Development requires thorough exploration, detailed engineering of site-specific producing facilities, and lengthy periods of onshore construction and offshore installation. Thus, it may take up to 10 years or more from initial leasing to first production – a fact reflected in the length of federal leases.

When ConocoPhillips bids for leases, we put a significant amount of capital at risk. We therefore bid with the intent of discovering and producing hydrocarbons. Initial lease bonus payments in the Gulf of Mexico can exceed $100 million for a particularly promising block, which is paid to the federal government even if no hydrocarbons are ever discovered. There is also an ongoing commitment to pay rental fees on the lease, and exploratory wells may cost as much as $180 million each. We would not expend such enormous amounts of capital if we were not serious about developing our leases. If, despite our best efforts, we determine that a lease lacks commercial hydrocarbons and cannot be developed, after the lease expires the acreage reverts to the federal government and can be reoffered for leasing. We also relinquish leases before they expire if we determine early on that they lack prospectivity.

The existence of undeveloped leases also reflects the fact that much of the acreage leased will, after being studied and tested, be found to not contain sufficiently large accumulations of hydrocarbons to be commercial. However, if a lease appears non-commercial after an initial drilling campaign, rather than relinquish it immediately, a company may retain it to determine if new technology or further geologic studies may make possible the discovery of commercial hydrocarbons, or enable production from small accumulations. In addition, the relatively small size of offshore leases often encourages companies to acquire adjacent leases, since a hydrocarbon accumulation on one may extend into others. Conversely, when one lease block proves unproductive, it may condemn the prospectivity of surrounding leases as well.

ConocoPhillips would likely invest greater amounts and likely produce more oil and natural gas in the United States if more federal acreage was opened in the nation's remaining unexplored areas. If new, less-explored and thus less-mature areas were available for leasing, the likelihood of significant discoveries would increase.

ConocoPhillips has demonstrated its willingness to invest in additional federal acreage. This year alone, we will invest more than $890 million for our high bids in Gulf of Mexico and Chukchi Sea lease sales. We also have significant exploration and development investments planned in North America. In 2008 alone, we plan to invest about $6.5 billion in North America, with two-thirds of that amount earmarked for the United States.

31) **As fuel prices rose over the past 6 years, has American demand decreased? Why or why not has this occurred? If gas taxes were increased, do you think demand would decrease? Did this happen in European countries when they imposed large gas taxes?**

U.S. gasoline demand grew by only 0.4 percent in 2007 and declined by 1.3 percent in the first quarter of 2008, compared to growth of 2.8 percent in 2002 (before crude and therefore gasoline price increases). This demand reduction is driven primarily by rising crude prices which in turn drove a doubling of retail gasoline prices in the U.S. in real terms since 2002. As a result of rising prices, the growth rate in total vehicle miles traveled in the U.S. first slowed, and then went into decline in 2007, after growing at an average rate exceeding 2.0 percent per year since 1990. The slowing economy has also played a role in slowing the growth in vehicle miles traveled this year. Consumers have also changed their vehicle preferences and are now purchasing more fuel efficient cars. For example, the number of light trucks (SUVs and pick up trucks) as a percent of new vehicle purchases has been declining since 2004.

An increase in gasoline taxes would likely further decrease demand but it would also adversely impact the economy unless the revenues were recycled back to consumers. In Europe, high gasoline taxes have contributed to total oil demand growing at about one-third the rate of oil demand growth in the U.S. over the last 15 years. For example, in the United Kingdom, gasoline taxes were two-thirds of the retail gasoline price last year. In contrast, sales taxes represented only 15 percent of the U.S. gasoline pump price last year.

32) **At current projections, when will your current reserves be depleted?**

At ConocoPhillips' current rate of global production and assuming no new reserves are added, our company will produce as much hydrocarbons as we have as reserves in about 12 years. This is very similar to the United States' overall reserve-to-production ratio. However, the company has an active exploration program to replenish its resource portfolio. In 2008 alone, we are planning on spending over $2.3 billion on exploration. The cost of developing these proven reserves is not insignificant. In future years, based on year-end 2007 costs, the company projects expenditures of $52 billion to develop these reserves and bring them into production.

Reserves-to-production ratios are often misinterpreted. They should probably be thought of as a working inventory level. As long as you continue to add reserves at the same rate as production, you can remain at the same reserves-to-production level for years. This will require an enormous amount of capital and be challenging to do without additional resources being made available for development.

33) When do you expect underdeveloped countries will reach a level to where they will begin to significantly buy oil for use? How will this affect supply and fuel prices?

Since 2005, almost all of the global oil demand growth has been in developing countries, with two-thirds of that growth in developing Asia. Segments of the population in developing Asian countries (e.g., China, India) have reached a per capita income level where they are rapidly increasing their purchases of cars and appliances. Since 2000, new car sales in China grew at an average rate of 37 percent per year. In contrast, oil demand in industrialized countries (OECD) has declined by 1 million barrels per day since 2005.

Rising developing country demand growth has been a driving force in the increase in world oil prices in recent years. Subsidies and price controls in many developing countries have also made demand less responsive to higher oil prices. That means that oil prices have had to rise to even higher levels to dampen demand such that the supply and demand balance is restored. The International Energy Agency projects that oil demand will grow by more than 13 million barrels per day in China and India alone by 2030, which will continue to tighten the world's supply and demand balance and maintain pressure on oil prices.

About 1.6 billion people in developing countries, or a little over a quarter of the population in the world, do not presently have access to electricity in their homes. About 2.6 billion people in developing countries are relying on traditional biomass for cooking and heating. Energy is a prerequisite to economic development. Success in making energy accessible to these people will put even more pressure on global energy markets. The implications are that energy needs to be used more efficiently in the U.S. and globally, and diverse sources of supplies need to be developed to allow new and existing energy users, including the United States, access at affordable prices.

34) If all conventional, alternative, and unconventional sources of oil in the U.S. were to be developed, how long would the supply last based on current estimates of increased usage?

It is not possible to give a definitive answer to this question due to significant uncertainties associated with estimating (1) the volume of hydrocarbons contained within the Earth's crust, (2) the pace and scale of technological advancements, including advancements that might reduce the demand for oil or allow for oil to be produced from alternative sources, (3) the rate of economic growth and its impacts on oil demand and (4) the impact of government policies on resource development and demand.

For discussion purposes, as shown in the table below, as of year-end 2005, 1,332 billion barrels of oil-in-place[12] had been discovered in the United States. Of this, 208 billion barrels had already been produced, leaving 1,124 billion barrels in place. About 190 billion barrels of this is estimated to be recoverable with conventional technologies (25 years of U.S. demand at 2007 consumption levels of 7.6 billion barrels[13]), and another 240 billion barrels is estimated to be recoverable with enhanced recovery technologies[14] (32 years of 2007 consumption).

Original, Developed and Undeveloped Domestic Oil Resources*

	Original Oil In-Place (BBbls)	Developed to Date		Remaining Oil In-Place (BBbls)	Future Recovery**		
		Conventional Technology (BBbls)	EOR Technology (BBbls)		Conventional Technology (BBbls)	EOR*** Technology (BBbls)	Total (BBbls)
I. Crude Oil Resources							
1. Discovered	582	(194)	(14)	374	0	110	110
- Light Oil	482	(187)	(2)	293	0	90	90
- Heavy Oil	100	(7)	(12)	81	0	20	20
2. Undiscovered	360	0	0	360	119	60	179
3. Reserve Growth	210	0	0	210	71	40	111
4. Transition Zone	100	0	0	100	0	20	20
5. Tar Sands	80	0	0	80	0	10	10
TOTAL	**1,332**	**(194)**	**(14)**	**1,124**	**190**	**240**	**430**

*Does not include oil shale.

**Technically recoverable resources rounded to the nearest 10 billion barrels.

*** Based on ten basin-oriented assessments and residual oil zone potential highlighted in reports released by the Department of Energy Office of Fossil Energy in February 2006.

This table updates the table of U.S. oil resources recovery potential in the report entitled, Undeveloped Domestic Oil Resources: The Foundation for Increasing Oil Production and a Viable Domestic Oil Industry, February 2006.

The United States Geological Survey estimates that there are 48.5 billion barrels of undiscovered, technically-recoverable oil within the United States. This would add another 6.5 years of production at 2007 U.S. consumption levels.

Another possible source of oil that is abundant in many parts of the world is "oil shale", which refers to a sedimentary rock that contains solid bituminous material that can be converted into petroleum-like liquids when the rock is heated. The largest known oil shale deposits are in the U.S., in Colorado, Utah and Wyoming. These deposits are estimated to contain 1.5 to 1.8 trillion barrels of resource, of which between 0.5 and 1.1 trillion barrels have been postulated as being recoverable with advanced technologies (between 66 and 146 years of U.S. consumption at 2007 rates).

As noted in response to Question 10, we believe that with the current and projected suite of available technologies and crop yields that a substitution of 10 percent (15-17 billion gallons per year) of biofuels in the transportation sector is feasible by 2015. Market penetrations beyond this level will require substantial breakthroughs in crop types and yields and conversion technologies. Given that biofuels may be able to be produced in perpetuity, they would extend the above calculated "years of consumption" for oil extracted from the Earth's crust by whatever percentage of the total oil consumption they replace.

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[12] Includes domestic heavy oil and tar sands, but not oil shale

[13] US DOE, EIA, http://tonto.eia.doe.gov/dnav/pet/pet_cons_psup_dc_nus_mbbl_a.htm

[14] National Petroleum Council, Facing the Hard Truth about Energy, Topic Paper #19, "Conventional Oil and Gas", page 3

Summing up the above noted "years of consumption" estimates, this would yield a total of between 130 and 210 years without biofuel contributions, with the total increasing to 142 to 230 years if biofuels meet 10 percent of current demand. Furthermore, as previously noted, biofuels production could presumably extend beyond the cessation of oil production. This estimate also does not include U.S. coal resources, which are considerable and can be converted into natural gas or liquids.

35) Please describe to this committee your short, middle, and long-term plans for oil and renewable energy development.

ConocoPhillips has initiated, or is planning, a significant number of major projects to develop oil and natural gas resources both domestically and internationally. In 2008, our planned capital program of $15.3 billion includes $12.0 billion of investment in Exploration and Production activities. In order to continue meeting current U.S. and global energy demand, it is important that we retain the opportunity to invest sufficient capital in economically viable traditional oil and natural gas development projects. The following table provides publicly available information related to ConocoPhillips' short-, middle- and long-term plans for oil and gas development:

Start-Up	Region	Significant Project	WI%	Gross Peak Production MBOED	Current Project Phase
Short-term (2008-2009)	Canada	Foster Creek 1D	50	22	Construction
		Foster Creek 1E	50	22	Construction
	Asia Pacific	Bohai Phase II	[redacted]	184	Construction
		North Belut	[redacted]	55	Construction
		Su Tu Den Northeast	23	30	Construction
	North Sea	Alvheim	20	90	Construction
		Britannia Satellites	[redacted]	85	Construction
	West Africa	N-LNG Train 6 supply	20	49	Construction
	Russia / Caspian	Yuzhno Khylchuyu (YK)	30[1]	150	Construction
	Middle East / North Africa	Qatargas-3	30	263	Construction
Medium-term (2010-2012)	Alaska	North East West Sak	[redacted]	30	FEED
		Ugnu	[redacted]	162	Appraise
	Canada	Christina Lake C-F	50	112	FEED
		Foster Creek 1F & 1G	50	54	FEED
	Asia Pacific	Suban 3	[redacted]	59	Concept
		Su Tu Trang	23	25	Appraise
		Su Tu Nau	23	48	Appraise
		Gumusut-Kakap	33	129	Construction
	North Sea	Jasmine	[redacted]	82	Appraise
		Eldfisk II	[redacted]	83	Concept
	Russia / Caspian	Kashagan Phase 1	8	450	Construction
	Middle East / North Africa	Libya - North Gialo	16	85	Concept
		Libya – Faregh 2	16	36	Construction
		Algeria – Elmerk (EMK)	17	54	FEED
Long-term (2013+)	Alaska	Prudhoe Gas Cap	36	500	Concept
		Mooses Tooth	[redacted]	52	Appraise
	Canada	Surmont 2	[redacted]	80	FEED
		Surmont 3&4	[redacted]	160	Concept
		Thornbury 1-2	[redacted]	89	Concept
		Clyden 1	[redacted]	44	Concept
		FCCL other	50	220	Concept
		Parsons Lake	[redacted]	56	FEED
		Amaugliak	[redacted]	94	Appraise
Long-term (2013+) cont'd	Asia Pacific	Sunrise	30	220	Concept
		Caldita / Barossa	[redacted]	77	Appraise
		Kebabangan	30[2]	145	Concept
	North Sea	Ekofisk South	[redacted]	72	Concept
		Tor Redevelopment	[redacted]	30	Concept
		Tommeliten	[redacted]	57	Appraise
		Clair II	24	60	Appraise
	West Africa	Brass LNG supply	20[3]	119	FEED
	Russia / Caspian	Kashagan Phase 2+	8	1,050	Concept
		Kalamkas	8	124	Concept
		Aktote	8	100	Appraise
		Kairan	8	70	Appraise
	Middle East / North Africa	Libya - NC98	16	90	Concept
		Libya - Dahra Jofra	13	56	Concept

Notes from table (previous page):
WI% = Working Interest
■ *= ConocoPhillips-operated project*
FEED = Front-end engineering design
[1] *Includes direct working interest only*
[2] *Jointly operated*
[3] *Represents equity in the upstream gas supply project. WI in liquefaction plant is 17%.*

Conventional oil and natural gas are, and will generally remain for the near and medium term, the lowest-cost feedstocks available for the production of transportation fuel. Despite the relative economy of these conventional supplies, we are increasingly focused on alternative and renewable energy sources. Development of alternative and unconventional energy sources will be essential in the future, but it is important to recognize that new technologies take time to commercialize and usually cost more than conventional supplies. The following table provides publicly-available information on our short, medium and long-term activities in renewable energy development.

Target	Activity	ConocoPhillips Role
Short-term (Clean/Unconventional Fuels)	Ethanol blending	• Large, rapidly expanding ethanol blending
	Biofuels	• E-85 is marketed under our branded canopy in a number of states - with over 2,500 potential sites - provided the marketer meets certain image, safety and fuel-quality guidelines • Selectively adding biodiesel blending • Producing vegetable oil-based diesel in Ireland • Test manufacturing animal fat-based diesel with Tyson Foods
Medium- / Long-term (Research)	Biomass fuels	• Joint agreement with Archer Daniels Midland to research development of fuels from agricultural waste
	Biofuels	• Major relationship with Iowa State University to research biofuels (advanced 26 projects in 2007-8)
	Renewable Power	• Created an internal business organization dedicated to evaluating opportunities to invest in solar, wind and geothermal projects • Reviewing opportunities to incorporate renewable energy to support our operations

In addition to development of oil and renewable energy sources, we continue to invest in our refineries and infrastructure to increase clean product yields, achieve better energy efficiency, and enable use of lower-cost feedstock in our refining processes. The following table provides a sample of some short- and medium-term projects in development or execution:

Investment*	Primary Investment Target Clean Products	 Energy Efficiency	 Lower Cost Feedstock	Investment Country or Region
San Francisco Refinery Hydrocracker	✓	✓	✓	U.S.
Los Angeles Refinery Conversion	✓	✓		U.S.
Ferndale Refinery Coker	✓		✓	U.S.
Billings Refinery Fractionation Upgrade	✓	✓	✓	U.S.
Bayway Refinery Fluid Catalytic Cracker		✓	✓	U.S.
Keystone Pipeline Construction			✓	U.S./Canada
Wilhelmshaven Refinery Upgrade	✓		✓	Germany
WRB LLC project (JV)[†]	✓	✓	✓	U.S.
Melaka Refining Company (JV)	✓		✓	Malaysia
Yanbu Export Refinery	✓		✓	Saudi Arabia

**Certain investments noted here are pending approval and permitting, and thus may not move forward.*

[†] *WRB is a U.S. refining joint venture with EnCana Corporation, consisting of the Wood River and Borger refineries.*

36) On Page 4 of your testimony, you specifically mention the Roan Plateau in Colorado as a site that could have potential for natural gas production. Do you have an estimate of how much natural gas is estimated to lie in that area?

The U.S. Department of Interior Bureau of Land Management estimated in 2004 that there were 15.4 trillion cubic feet of technically recoverable gas resources within the Roan Plateau Planning Area, which is approximately 59 percent owned by the federal government (remainder is private lands).

37) How do you think we could best find a balance between federal, state and local interests as we work through the permit process?

ConocoPhillips is sensitive to the interests of all stakeholders who are potentially impacted by our operations, including federal, state and local governments and citizens. While we agree that all such viewpoints are entitled to be heard in the regulatory process, there are certain critical infrastructure needs that merit expedited review and processing. As pointed out in our earlier testimony, ConocoPhillips has encountered significant delays in such critical projects, due to the length of the regulatory process. The most recent example is the proposed expansion at the Wood River refinery, where the permitting process has been in process since May 2006, and has delayed construction to this point. When it is in the national interest, Congress should expedite federal and state permitting processes to ensure a balance between federal, state and local and special interests.

38) On Page 5 of your testimony, you quote the National Petroleum Council's report on the need for increased rail, waterway, and pipeline transportation as we develop renewable fuels. Do you have any idea what kind of investment is necessary to provide the infrastructure that is necessary?

We are not aware of any existing studies that focus on the costs of transportation infrastructure required to expand biofuels use in the U.S. to 36 billion gallons as is presently mandated. We believe this is an area that needs further study.

We are participating in a task force (along with other experts from industry, finance, government, environmental organizations and academia) convened by the National Commission on Energy Policy to examine ethanol distribution issues. This work will focus on the distribution implications of a large increase in ethanol production and the policy and regulatory measures that might facilitate an efficient ethanol distribution network.

39) You also mention the investment required to maintain the infrastructure for current oil and gas production – do you have any figures on that investment?

According to the International Energy Agency, $9.6 trillion of investment will be required between 2006 and 2030 to supply the required oil and natural gas production. About two-thirds of this investment is for upstream or exploration, development and production spending. Thus, about $3.3 trillion will be needed for downstream infrastructure.

40) With regard to your project using by-product animal fats and grease to make bio-fuel, you note that this could potentially use the current pipeline system – is that because the fuel would contain less water? Or what other factors come into play as you make that decision?

The renewable diesel manufactured at our Borger refinery from animal fat feedstock is chemically similar to ultra low sulfur diesel fuel. Therefore, it has no compatibility issues with either the existing distribution infrastructure or vehicles.

In contrast, biodiesel is a chemically different fuel produced from similar feedstock. This fuel contains oxygen groups which have an affinity for water and are not found in conventional diesel fuel. This affinity for water presents infrastructure and vehicle concerns which have limited biodiesel's ability to be shipped in multi-product pipelines. The industry continues to evaluate how to integrate biodiesel blends into pipelines.

41) Could you explain what the problem is with the language on blending tax that does not allow you to compete with other renewable and biodiesel fuel producers?

The language in H.R. 5351 would reduce retroactively the credit for the co-production of renewable diesel from $1.00 per gallon to 50 cents per gallon, rendering the process uneconomic and also uncompetitive with biodiesel manufacture which utilizes similar feedstock and has similar economics. The greater tax credit for biodiesel will allow biodiesel manufacturers to pay more for feedstock than renewable diesel co-processors, and thereby price renewable diesel processors out of the market.

We believe that Congress should avoid picking technology winners and losers. This change in tax code violates not only this principle, but also committee members' own admonitions to the oil industry to increase our investment in renewable fuels and other alternatives sources.

Renewable diesel offers outstanding greenhouse gas and criteria pollution reduction. It is fully compatible with both the pipeline distribution system and vehicles. It allows for biofuels production from non-food sources. Deployment of co-processing requires capital investment in our refineries, but since it utilizes some existing reactor capacities it allows for a more rapid deployment and better economic viability than a pure stand-alone option. Finally, only the portion of the fuel directly created from renewable feedstock qualifies for the tax credit. No petroleum processing is subsidized.

Tax uncertainty has limited our deployment of the technology to a small test installation at our Borger, Texas refinery. For the first five months of this year, our operation has co-produced about 300 barrels per day of renewable diesel. Without the full tax credit this operation would not have been economic, even before capital recovery. This tax change will likely force us to cease renewable diesel production in the United States and focus on our European refineries.

Finally, the retroactive nature of this change does little to encourage oil companies to experiment with new, superior technologies.

42) You mention that recent tax proposals would reduce funds available to invest in developing new energy supplies – do you have an estimate of how much that would be?

H.R. 5351 is estimated to increase taxes on our industry by $18 billion over ten years. That is $18 billion less funds available for investment, including those for new supplies of oil and natural gas.

43) On Page 8 of your testimony, you note that you are test marketing E-85 in a number of states. What have you learned from this experience?

The feedback we have received from most of our branded gas stations who have installed E-85 dispensers is that there is insufficient demand to justify the expense of the conversion. The problem is that only 3 percent of the U.S. passenger fleet possesses flexible fuel capability today and consumers who own these vehicles are often unaware of it. In addition, consumers are concerned about the roughly 25-percent reduction in gas mileage experienced when using E-85 fuel versus conventional gasoline.

44) What is it about the vegetable and animal fat feed stock that allows you to create a better blend of diesel fuel that does not have the same performance issues as bio-diesel?

The superior properties of renewable diesel are not feedstock dependent but rather an advantage of the chemical process used to create the end product. Renewable diesel is chemically similar to ultra low sulfur diesel and therefore has no compatibility issues with either the existing distribution infrastructure or vehicles. In fact, the specific diesel molecules created actually improve certain performance characteristics of ultra low sulfur diesel.

In contrast, biodiesel is a chemically different fuel produced from the same feedstock. This fuel contains oxygen groups which have an affinity for water and are not found in traditional diesel fuel. This affinity for water presents infrastructure and vehicle concerns which have limited biodiesel's ability to be shipped in multi-product pipelines. The industry continues to evaluate how to integrate biodiesel blends into pipelines.

45) What types of agricultural waste products look like they have the most potential for bio-fuels production?

Assuming that there is no material difference in the ability of the conversion technology, the highest potential feeds are those that can easily fit in the existing agricultural harvesting and transportation infrastructure. Starting with already stranded items like corn fiber and wood chips seems the most likely early sources to be commercially viable. The next most likely sources are corn cobs and stover and wheat and rice straw as some of these products can be sustainably removed from the field and can also leverage the existing gathering and transportation infrastructure and firms.

46) Based on your experience with lithium-ion battery development, what do you think needs to be done to develop more battery technology for cars and other high-energy use applications?

We believe lithium-ion batteries are best suited for use in hybrid and other electrical vehicles and are likely to become the battery of choice for vehicular applications in the foreseeable future. There are many areas of development that could improve their performance for application in autos. Material improvements need to be made to extend the operating temperature range of batteries so they can be used in winter in Minnesota and summer in Arizona. These materials need to be safe and provide long cycle life for the battery to last as long as the car does.

Research and development efforts should continue seeking reductions in battery material costs and also cost reductions in near-zero defect manufacturing processes needed to ensure safety. Progress in both areas is needed to make the batteries more economic. Data needs to be collected on these new generation batteries to ensure safe and reliable operation in automotive service. Today, most lithium-ion batteries are made in Asia. Enhanced battery R&D and manufacturing infrastructure in the United States is needed to avoid over-reliance on foreign supplies and imports.

47) How would you rate your experience with the Freedom CAR and Fuel Partnership initiatives? Is there more that we should be doing in those programs that would help curb the demand for gasoline?

There is little that the FreedomCAR and Fuel Partnership program can do to reduce near-term gasoline demand. Near to mid-term reductions in gasoline demand will be accomplished with automotive technologies already being commercialized or close to commercialization. Hybrid vehicle sales are now in the hundreds of thousands annually and many automakers are developing plug-in hybrids and pure electric vehicles with serious commercial intent. The auto industry is also rapidly introducing increasingly energy efficient non-hybrid advanced gasoline and diesel-based powertrains and is shifting product mix toward higher fuel economy vehicles in response to strong consumer demand.

The five energy partners, including ConocoPhillips, have staffed the hydrogen-related technical teams with well-qualified senior scientists and engineers. As detailed in Chapter 5 of the National Research Council's recently released *Review of the Research Program of the FreedomCAR and Fuel Partnership - Second Report*, formidable technical and economic barriers must still be overcome before fuel cell vehicles and hydrogen fuel can be commercialized. R&D directed at these difficult problems remains an appropriate role for the federal government. High technical risk and long lead times to market tend to temper private sector investment in fuel cell vehicle-related technologies.

The FreedomCAR and Fuel Partnership is appropriately focused on high technical risk, long lead time R&D. Nevertheless, it is unlikely that fuel cells and hydrogen will significantly reduce transportation energy demand within the next 25 years. It is also possible that fuel cell vehicles may not be significantly commercialized if lithium-ion battery technology enables successful commercialization of plug-in hybrids and pure electric vehicles delivering consumer value and other benefits similar or superior to those that fuel cell vehicles might offer.

48) What are the major benefits of syngas? Where are you in terms of scale deployment of a syngas project?

Syngas or synthesis gas from the gasification of coal or petroleum coke can be used directly to fuel combustion turbines in Integrated Gasification Combined Cycle (IGCC) power plants. Alternatively, the hydrogen that is the main component of syngas can be extracted for use in conventional crude oil processing, for ammonia production in fertilizer plants or as a fuel for power plants with advanced combustion turbines or fuel cells.

Syngas is also the intermediate feedstock for a number of different conversion processes such as Fischer Tropsch coal-to-liquids (which produces diesel, jet fuel, and naphtha), SNG (which makes Substitute Natural Gas or methane), and other processes that make DME, methanol and gasoline.

ConocoPhillips owns and markets the E-Gas^{TM} technology for Solid Fuel Gasification, which has been commercially proven at utility scale (200-300 MW per equipment train) on sub-bituminous and bituminous coals and petroleum coke. The Wabash River IGCC facility in Terre Haute, Indiana (one of the two IGCC plants in the U.S.) utilizes the E-Gas^{TM} technology and has been operational since 1995. ConocoPhillips provides professional services and technical expertise for operations and maintenance to the owners of that facility, as well as using it as a base for continued technology research and development.

ConocoPhillips is now actively conducting feasibility studies on two gasification projects for equity participation. The first one is in conjunction with Peabody Energy in Kentucky, which would use the ConocoPhillips proprietary E-Gas^{TM} technology to produce syngas from a blend of coal and petroleum coke (approximately 10,000 tons per day) which would then be converted into pipeline quality methane (natural gas, 50-70 billion cubic feet per year). The second project is at the ConocoPhillips Sweeny refinery in the Texas Gulf Coast. This project plans to produce syngas from refinery-sourced petroleum coke (about 5000 tons per day) for use in the associated cogeneration power plant, or in producing methane and hydrogen. These will be among the largest coal or coke-fueled gasification facilities in the world and could both be operational in the 2014-2016 timeframe if the studies prove them to be economically viable. Options for carbon capture and sequestration are being evaluated for both of these projects.

ConocoPhillips is also marketing and licensing the E-Gas^{TM} technology to other companies, with three executed licenses for new projects in the U.S. in the last five years (none of these projects has entered construction at this time).

49) If you were going to propose a legal and regulatory framework for carbon capture and storage, what would you propose as the key elements?

ConocoPhillips believes that CO_2 capture and storage (CCS) will play an important role in reducing U.S. greenhouse gas (GHG) emissions. It will also strengthen U.S. energy security by improving the acceptability of using the vast coal resources in the United States. Widespread deployment of CCS will require national legislation that establishes a value for carbon emissions, supports technology research and development, provides incentives for early movers, and creates a regulatory and legal framework that provides the certainty necessary for long-term investment while letting market forces drive the most cost-efficient and environmentally effective CCS solutions.

CO2 Capture

While existing laws and regulations may be sufficient to handle the capture aspects of CCS, certain issues remain to be addressed.

Permitting

In general, permitting processes for CO_2 capture equipment and facilities must be streamlined and efficient with clear lines of authority established as soon as possible in order to enable new construction and modifications to existing plants. The government should avoid establishing Best Available Control Technology (BACT) standards in the permitting process for industrial and power CCS applications. The market price for GHG emission allowances will determine the most cost effective GHG reduction investments.

CO_2 and criteria pollutants

Some CO_2 capture technologies may yield additional criteria pollutant emissions due to the need for oxygen production for oxy-firing, steam for amine stripping, power use for CO_2 compression, etc. Clear regulatory guidance on how to address these trade-offs will be important.

CO2 Transport

Procurement and permitting of rights-of-way

A regulatory framework should be implemented to enable procurement and permitting of rights-of-way for intrastate and interstate CO_2 pipelines. This could be done in a manner analogous to natural gas pipelines. Regulation of the operation of CO_2 pipelines can be effectively handled by existing Department of Transportation rules.

CO2 Storage

Access to pore space

- Ownership of storage rights needs to be clarified.
- A mechanism should be established to enable consolidation of all of the storage interests in a project area by the project operator.
- Rules should be established governing the area over which storage rights must be acquired by the storage operator, taking into consideration CO_2 plume expansion and pressure impacts.
- The pore space acquisition rules should contemplate modification of the storage area during the operational phase of the project to account for unanticipated movement of injected CO_2 and/or project expansion.

Permitting requirements

The U.S. EPA is currently developing regulations governing permitting, construction and operation of CO_2 storage sites. We suggest that several principles guide development of regulations for CO_2 storage sites:

- Regulations should be stringent enough to ensure responsible site selection, development and operation that minimizes the risk of leakage of CO_2 into drinking water sources and the atmosphere. In addition to minimizing risk to human health and the environment, this principle should improve stakeholder acceptance of CCS as a climate change mitigation strategy.
- Regulations should be flexible enough to allow site-specific implementation of appropriate construction, monitoring, mitigation and verification techniques.
- Regulations should be adaptable to allow for modifications as experience is gained, given that regulations are likely to take effect before many large CO_2 storage projects are in operation.

Treatment of the various types of storage reservoirs
Future storage reservoirs for CO_2 are expected to include deep saline formations, depleted oil and gas reservoirs, and deep unmineable coal seams. In some cases, injected CO_2, in addition to being stored, may provide economic benefit by enhancing production of oil or natural gas from the reservoirs. The enhanced production of hydrocarbon resources associated with CO_2 storage provides a dual benefit by improving domestic production while enabling CCS projects to occur at lower carbon prices; hence a lower cost to society.

We believe that a legal framework for CCS should treat all forms of CO_2 storage equally. In particular, CO_2 storage projects which enhance hydrocarbon production should not be disadvantaged in terms of CO_2 credit allocation or application of early CCS incentives. Critically, CO_2 credits should be awarded in a timely manner to all types of CO_2 storage projects to avoid inflating the CO_2 price at which CCS projects become economically viable.

Long-term liability
Long-term liability issues associated with CO_2 injection can be managed with sound science, sound project management, operation and monitoring, and sound/consistent regulation.

50) In your testimony, you mention international research that has been conducted in several areas. Where do you think the United States ranks in terms of supporting research for energy development? What about carbon footprint mitigation?

ConocoPhillips has not tracked research and development spending by governments around the world. However, the International Energy Agency's recent publication, "Energy Technology Perspectives 2008: Scenarios and Strategies to 2050," indicated that Energy research development and demonstration (RD&D) budgets in many member countries declined between the early 1980s and the 1990s from $18 billion (USD) in 1980 to $8 billion (USD) in 1997. This decline was largely associated with the difficulties of the nuclear industry and with the decrease in oil prices from 1985 to 2002. Since 1999, government expenditures on RD&D have slightly recovered and stabilized; they were estimated to be $10 billion in 2006. However, over the same timeframe, energy RD&D as a share of total RD&D declined from 11 percent in 1985 to 3 percent in 2005.

This report also showed that the U.S. spends a smaller percent of its GDP on energy RD&D (3-4 percent) than France (~5 percent) and Japan (~9-10 percent).[15]

Similarly, the figure below included in the National Petroleum Council study on "Facing the Hard Truths about Energy," shows U.S. government R&D funding for oil and natural gas has declined significantly in recent years.[16]

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[15] International Energy Agency, "Energy Technology Perspectives 2008: Scenarios and Strategies to 2050," 2008, page 172

[16] Cited in National Petroleum Council, "Facing the Hard Truths about Energy," page 176, with the original source of Lawson, William F, "Who Will Fund America's Energy Future?" Interstate Oil and Gas Compact Commission Report, 2006

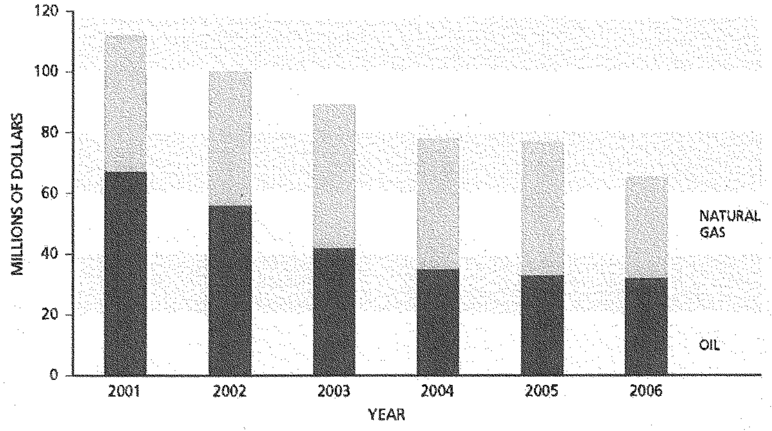

FIGURE 3-5. Oil and Natural Gas R&D Funds Provided by the U.S. Government

In most OECD countries there is consensus that the government should invest in basic science and technology research to complement the nearer-to-market technology investments that the private sector will be prepared to make. However, the U.S. government proposal for fiscal year 2007 to terminate the oil and natural gas program within the Department of Energy leaves only $50 million in royalty receipts that were set aside in the Energy Policy Act of 2005. The bulk of the funds ($35 million) were set aside for ultra-deepwater and unconventional-hydrocarbon research programs as part of the Research Partnership for a Secure Energy America (RPSEA). The remainder ($15 million) is set aside for an internal National Energy Technology Laboratory program and administrative funds.

Climate change is a global challenge that will require a suite of solutions including sound policy, innovation and participation by governments, industry and consumers. A national mandatory policy on climate change will provide the basis for the United States to assert world leadership in environmental and energy technology innovation. The cost-effective deployment of existing technologies to improve energy efficiency and reduce GHG emissions should be a priority. Government should not try to pick "winners" among the competing technologies but should let the market choose the best, most-efficient energy sources. The U.S. can demonstrate leadership by a multi-pronged technology approach that encourages private investment in a variety of low-carbon energy sources while continuing government-funded research and by increasing support of education - particularly in the technical skills that are so critical to our energy future.

51) I applaud your efforts in recycling water in some of your operations. What, if anything, can Congress do to help support water use policies such as this?

Our growing world must have water for human survival and reliable fresh-water supplies are increasingly scarce. Recognizing this need, ConocoPhillips is committed to conserving and protecting fresh-water resources, and to enhancing the efficiency of our water utilization.

Crude oil production on average produces three to four barrels of water for each barrel of oil. This excess of produced water usually contains too much natural salt and minerals to be of agricultural or residential use. In order to reuse as much as possible, we reinject much of this to help maintain reservoir pressure and recover additional natural resources. We reuse some of it in other applications and dispose of the rest as permitted by applicable law.

Efforts that are being undertaken by industry that have broad application should be supported through financial support for research and development, regulatory support and financial innovation. That support could be used to find alternative uses for water we process, develop novel technologies to purify produced water, promote innovations to reduce water from natural resource recovery, and explore partnerships with local agencies to look at water management and municipal collaboration. In addition, sponsorship of programs to increase awareness and encourage water conservation through exhibitions and workshops would be of value.

To encourage quicker adoption of technologies or processes which can benefit the entire watershed, incentives could be put in place to minimize the cost and other constraints. Congress could consider various options to encourage quicker adoption through tax credits for capital deployed to increase recycling, incentives for sponsoring research and development efforts, or a simplified permitting process for technology prototypes. Finally, reducing the cost and barriers to the reuse of treated municipal waste for industrial processing should be encouraged in regions that are water stressed.

52) What would listing of the polar bear as an endangered species do to your potential oil development in the Chukchi Sea? And do you believe that polar bears or their habitat would be harmed by oil operations in that area?

ConocoPhillips has extensive experience on Alaska's North Slope and has found that polar bears can coexist with energy activities. Available scientific data indicates that the bear population that is active near North Slope operations has been healthy and sustainable for more than 20 years. Also, exploration in the Chukchi Sea would be conducted in open water during the summer when polar bears have a limited presence, making it highly unlikely that polar bears would be disturbed during the exploration activities. No bears were sighted during a recent 90-day seismic survey.

53) What kind of investment did Conoco-Phillips make in the Rockies Express pipeline? Are other pipeline projects under consideration?

ConocoPhillips made an equity investment in the Rockies Express natural gas pipeline to support our natural gas production in the San Juan Basin and other neighboring producing areas. Additionally, ConocoPhillips has taken an equity position in the recently announced Keystone pipeline which will transport heavy crude oil volumes from Western Canada's oil sands region to U.S. refining centers. ConocoPhillips also has announced that it is currently developing the Alaska North Slope pipeline as part of the Denali Joint Venture. Also, ConocoPhillips continuously considers and evaluates the benefits and risks of taking an ownership position in various crude oil, refined products, and natural gas pipelines along with related infrastructure. With respect to existing pipeline systems within the ConocoPhillips portfolio, ConocoPhillips regularly evaluates opportunities to optimize assets which may include expansions, consolidations, facility upgrades or reconfigurations, and ownership changes.

54) How does your experience with LNG terminals in the US differ from sites you are developing around the world?

Many gas-consuming countries around the world recognize the value of natural gas to their sustainable economic and environmental well-being and have embraced the benefits for having a reliable and diversified gas supply. Accordingly, many have included importation of LNG as a critical component of a policy or strategy for meeting their long-term energy supply needs. Having the foundation of a strong energy policy which recognizes the importance of a diversified energy portfolio, including LNG, creates an atmosphere that is conducive to people wanting to be informed with facts and support projects from which they and their country will benefit.

The acceptance of LNG receiving terminals in the U.S. and in other countries varies from country to country and from location to location. In the U.S., we have found that communities are divided on their acceptance of LNG terminals. Some members are being swayed by inaccurate information when in fact the LNG industry has an excellent safety record for more than 40 years. ConocoPhillips is committed to working with the federal, state and local government and citizens where we live and conduct business to help find solutions that meet our energy needs while maintaining our quality of life. We believe that as the world's largest natural gas-consuming country, the U.S. needs a comprehensive, long-term energy policy and that LNG should be included in this policy.

ConocoPhillips has been or is involved in the development of a number of LNG receiving terminals in the U.S., including the Freeport terminal in Freeport, Texas, the Golden Pass terminal near Sabine, Texas, Compass Port off the coast of Alabama, Sound Energy Solutions at the Port of Long Beach, California and a project in Harpswell, Maine. Internationally we have been involved in projects in Teesside, U.K., the Port of Eemshaven in the Netherlands and Singapore.

55) What kind of tax base does Conoco-Phillips provide for Alaska? And those funds could be used for climate mitigation for native villages, couldn't they?

ConocoPhillips Alaska, Inc. alone paid approximately $1.8 billion in taxes to the state of Alaska and Alaska municipalities in 2007. This figure does not include the oil and gas royalties ConocoPhillips paid to the state in 2007, a portion of which was deposited in the Alaska Permanent Fund. The state of Alaska's decision to increase its petroleum profits tax (PPT) rate in late 2007 significantly increased the Alaska state tax burden on our ongoing oil and gas operations, and that increased tax rate will be reflected in our 2008 Alaska tax payments.

Over the last four years, the state of Alaska has changed their tax structure to significantly increase taxes on the oil and gas industry three different times. This not only increases the costs associated with oil and gas production and developments, but also adds uncertainty to the predictability of the fiscal structure in Alaska going forward. These tax increases have had and will continue to have a chilling impact on investment in Alaska. Some major projects have been cancelled or deferred in late 2007 and early 2008, due at least in part to tax impacts.

In 2007, the state collected over $5 billion in revenues from the petroleum industry, primarily through corporate income taxes, severance taxes, property taxes, royalties and lease bonuses. The Alaska Department of Revenue projects petroleum revenues will rise to $8.9 billion in 2008. The Department of Revenue also estimates that petroleum revenues, which represent about 87 percent of the revenues of the state's general purpose unrestricted funds, have provided cumulative revenues to the state of $66 billion since 1959, and they project it will rise to $142 billion by 2017.[17]

The distributions of Alaska's tax revenues, including decisions on whether to allocate them for climate change mitigation for native villages, are decisions for the state of Alaska.

56) You briefly touched on the use of nanotechnology – what areas of energy exploration and production hold the most promise for improvement through the use of nanotechnology?

The oil industry is currently increasing our review and research of potential nanotechnology applications in an effort to improve operational efficiencies and to increase total hydrocarbon recovery from reservoirs. Nanotechnologies that appear to have the greatest potential for application in the oil industry fall into one of three major categories: (1) material science, with strengthening and weight reduction applications, (2) use of nanosensors for increased feedback from facilities, wells, and reservoirs, and (3) nanotechnology in oilfield chemical delivery both in facilities and in downhole reservoir applications.

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[17] Alaska Department of Revenues, "Revenue Spring 2008 Forecast," Figures 1 and 10, April 10, 2008

Material science
The use of carbon nano tubes and nano "enhanced" engineering materials have resulted in construction materials of super strength, low corrosivity and less weight. This makes these materials ideal candidates for selective use in offshore construction and operations. Applications of nano particles embedded into drill bits have resulted in longer lasting drill bits, for example.

Nanosensors
Nanosensors will include new and improved methods of gathering downhole data, i.e. pressures, temperatures, salinities and water cuts from oil wells, such that they can be operated and managed in a more efficient manner to increase recoveries and improve operations. Ultimately the industry would like to develop nano sensors that could be injected into reservoirs such that spatial information about oil, water, and gas saturations, geology of the reservoir including fractures, compartments, layering, and fluid injection patterns could be determined remotely. In this manner, improvements in reservoir and geological models could be implemented and reservoirs could be managed to increase ultimate hydrocarbon recovery.

Downhole delivery system
Nanotechnology is being applied in the development of new and improved methodologies and products classified as "oil field chemical delivery systems." Some specific applications currently include water-soluble polymers for application in injection water diversion and formulations of nano-sized particles being tested for their ability to increase the recovery of oil from reservoir rocks. Nanotechnology has the potential to increase the efficiency of enhanced oil recovery chemicals, improve waterflooding operations, produce more effective scale and corrosion chemicals, etc. Although nanotechnology is relatively new to the oil industry, there is considerable research effort on-going by vendors, suppliers, universities and major operators with the goal of accelerating the development of applications.

Our responses to the requests made by the Select Committee on Energy Independence and Global Warming of the U.S. House of Representatives contain forward-looking statements within the meaning of the "safe harbor" provisions of the Private Securities Litigation Reform Act of 1995. Actual outcomes and results may differ materially from what is expressed or forecast in such forward-looking statements. Economic, business, competitive and regulatory factors that may affect ConocoPhillips' business are generally as set forth in ConocoPhillips' filings with the Securities and Exchange Commission.

1) How much did your company invest in renewable energy technologies by year and by project over the last 10 years?

BP hereby provides the information for the last 5 years. It does not have 10-years' worth of this information available because of its various mergers and acquisitions over that time period.

Alternative Energy Capex $m

	2003	2004	2005	2006	2007
Solar US	8	10	21	12	42
Solar non-US	16	5	33	56	87
Solar Total	24	15	54	68	130
Wind US	0	0	0	410	246
Wind non-US	14	0	10	14	95
Wind Total	14	0	10	423	341
Hydrogen Energy US	0	0	0	0	0
Hydrogen Energy non-US	0	0	0	18	18
Hydrogen Energy Total	0	0	0	18	18
Biofuels US	0	0	0	0	0
Biofuels non-US	0	0	0	0	76
Biofuels Total	0	0	0	0	76

Total US Capex	8	10	21	422	289
Total non-US Capex	29	5	43	88	276
Total Capex	**37**	**15**	**64**	**510**	**565**

2) How much does your company plan on investing in renewable energy technologies by year in coming years?

To date, BP Alternative Energy has invested $3 Billion. This includes projects in Wind, Solar, Hydrogen power, CCS and Biofuels. BP recently announced that it was doubling its annual rate of investment in alternative energy to $1.5 Billion.

3) Based on the fundamentals of supply and demand, what does your company estimate the price of oil should be were it not for speculation, and other factors? Mr. Simon from ExxonMobil testified that their analysis of fundamental supply and demand suggests a price of oil in the $50-55 range, and prices above that figure are due to speculation, weakening dollar and geopolitical stability. Do you agree or disagree with that analysis?

BP agrees with the CFTC, which has concluded that "there is little evidence that changes in speculative positions are systematically driving up crude oil prices." In *his April 3, 2008 testimony before the Senate Committee on Energy and Natural Resources, CFTC Chief Economist Jeffrey Harris stated:*

> *Given the relative stability of the makeup of participants and their positions in the markets and the absence of evidence that speculation has caused oil price changes, it appears that fundamentals provide the best explanation for crude oil price increases. These fundamentals can be either broad factors that affect many markets—like the value of the dollar or general inflation fears—or factors particular to a market—such as strong demand from China and India for crude oil and other commodities. In addition, geopolitical events, such as tensions involving Venezuela, Nigeria, Iran, Iraq, Turkey and the Kurds have affected commodity markets, especially the energy and precious metals markets.*

The price of crude oil reflects the forces of supply and demand as they exist at any given time – it is not possible to say what the price of crude oil "should be" apart from those market forces of supply and demand.

4) What percentage of the current price of oil is a result of speculation?

See our answer to Question 3.

5) How much did your company invest last year in emerging energy technologies in North America and what types of technologies would that include?

The chart below shows our research and development spend in alternatives for the last five year period.

R&D Spend ($m)

	2003	**2004**	**2005**	**2006**	**2007**	**TOTAL**
Solar	*5.4*	*4.0*	*6.1*	*8.2*	*8.2*	*31.9*
Renewables & Alternatives / AE Technology (Wind, Hydrogen power)			*9.4*	*8.3*	*27.7*	*45.4*
Biofuels			*5.0*	*7.2*	*14.3*	*26.5*
Energy Biosciences Institute (CA Berkeley, IL Urbana)				*2.5*	*26.0*	*28.5*
Hydrogen for Transport	*10.0*	*10.0*	*10.0*	*10.0*	*10.0*	*50.0*
TOTAL	*15.4*	*14.0*	*30.5*	*36.1*	*86.2*	*182.2*

6) In 2030, what percentage of global energy demand will be met by fossil fuels?

Future energy demand growth is highly uncertain. It will be influenced by (among other factors) economic growth, energy prices, technological innovation government policy. The National Petroleum Council in its recently issued study, "Facing the Hard Truths About Energy", concluded that energy demand will grow by 50-60 percent by 2030. Further, it projects that more than 75 percent of future energy demand will be met with fossil fuels (oil, gas, coal).

7) Do you think that it is important as an energy security issue, to use more of the US reserves of oil and natural gas? What are the best policies to assure our energy independence?

Policies that allow for the continued development of all US energy resources (oil, gas, coal, nuclear, wind, solar, biofuels, alternatives) are essential to meeting the future energy needs of US consumers. There is no single energy source that is capable of supplying US energy needs. It will take a portfolio of options including access to resources, legal and regulatory certainty, economy-wide carbon price and transitional incentives to enable resources of all types to be adequately developed.

8) What percentage of your stock is own by pension plans and retirement accounts?

The chart below shows the ownership interests in BP stock by category.

Beneficial Owner Composition

Register Date: 31 March 2008

Threshold: 100,000 shares and above

Issued Share Capital: 19,039,435,263

BREAKDOWN BY CATEGORY		
Type	*Shareholding*	*% of ISC*
ADR	5,399,242,422	28.36%
Unit Trusts	3,713,986,715	19.51%
Pensions	2,794,111,497	14.68%
Other	2,261,149,205	11.88%
Insurance	1,353,406,799	7.11%
Private Client Brokers	772,052,073	4.06%
Foreign Government	320,470,926	1.68%
Retail Investors	289,982,724	1.52%
Marketmaker	231,407,236	1.22%
Inv Trusts	128,310,637	0.67%
Charities	127,668,152	0.67%
Directors	103,492,821	0.54%
Custodian	92,470,556	0.49%
Stocklending	46,115,000	0.24%
Arbitrage	36,797,556	0.19%
Clearing	28,730,636	0.15%
UK Government	21,677,633	0.11%
DBV Accounts	18,648,374	0.10%
Brokerage	11,342,356	0.06%
Employees Holdings	9,910,991	0.05%
Hedge Funds	1,168,024	0.01%
Family Holdings	403,932	0.00%
Below Threshold	848,380,603	4.46%
Unidentified	428,508,395	2.25%
SHARES IN ISSUE	**19,039,435,263**	**100%**

9) Do you support the use of coal-to-liquids as an alternative to traditional petroleum? If not, why not? As a follow up, wouldn't the use of coal-to-liquids significantly increase our domestic supply of fuel?

BP is not actively pursuing coal to liquids technologies but does support its inclusion in the future US energy portfolio. We believe it will take the development of all economic energy sources to meet the future needs of US consumers and thus no option should be removed from consideration.

10) How much bio-fuel and ethanol do you think realistically can be substituted for traditional petroleum?

We believe that biofuels have the potential to make-up 25 to 30% of the US transportation fuels pool by 2030.

11) Are you involved in developing production in Canada's oil sands or Western oil shale? Do you believe those alternatives will become more viable if the price of oil continues to rise?

BP recently completed a joint venture with Husky Energy to jointly develop its Sunrise oil sands field in Alberta, Canada. Oil from this field will supply our JV refinery in Toledo, OH which will undertake a modernization and expansion over the next several years. This expansion will result in the incremental supply of more than 600,000 gallons/day of transportation fuels to the Midwest market.

BP expects development of Canadian oil sands to accelerate in the coming years as safe, stable and secure resource to the US.

12) The American Jobs Creation Act provides a tax credit of up to $1.00 per gallon for the sale and use of "agri-biodiesel" -- biodiesel from virgin agricultural products. The credit is $0.50 per gallon for biodiesel from recycled grease. In addition, the law provides an excise tax credit for biodiesel blends (i.e., biodiesel and conventional diesel). Producers are eligible for one credit or the other, but not both. The Energy Policy Act of 2005 extends these credits through 2008. Do you support making these credits permanent? Do you support increasing these credits?

BP is not actively engaged in bio-diesel research or manufacture. However, BP supports the use of transitional incentives to enable the development and deployment of alternatives of all kinds. Properly structured, they should enable scale, reduce manufacturing costs and help achieve market competitiveness over time.

13) Do you support suspending or reducing the number of "boutique fuel mixes" that each state mandates in order to reduce gas prices in the near future?

Yes, boutiques add complexity to the supply and distribution of transportation fuels across the US and make response to supply disruptions difficult. The impact of these policies may be higher prices for the consumer.

14) Do you believe that the Energy Independence and Security Act of 2007 went far enough to access US oil and natural gas resources?

No. EISA 2007 did very little to enhance the opportunities to develop new oil and gas resources in the US.

15) Are you actively pursing carbon sequestration and Enhanced Oil Recovery in your oil fields and has that work been successful? What more needs to be done in this area?

BP is actively pursuing carbon capture and sequestration (CCS) technologies as part of its alternative energy portfolio. CCS is being used in our CA Hydrogen power project that will convert petroleum coke into hydrogen and use the resulting CO2 for enhanced oil recovery and sequestration in mature oil fields in California. In order for CCS to develop further, a fiscal, regulatory and legal framework is necessary that *will outline the measurement, monitoring and environmental requirements associated with future projects.*

16) What is a ballpark figure of how much your company pays in taxes each year?

Over the last several years BP has paid an average of $13 billion in taxes. This figure includes income taxes, property taxes, excise taxes and production royalties. If in-kind royalties are included, this amount increases to $14 billion/year.

17) A couple of you mentioned the National Petroleum Council repot "Facing the Hard Truths about Energy" do any of you disagree with the findings of that report?

No, the NPC report is the most in-depth, comprehensive review of the entire energy sector and benefited from the participation and support of a diverse group of stakeholders. BP endorses its findings.

18) Several of you mentioned the increasing cost of materials, difficulty in finding labor and specifically difficulty in finding engineers and scientists in oil and gas development. What policies do you think would help get the materials and people that you need?

Infrastructure investment (human, financial, industrial) typically follows clear, stable, long-term policy direction. Students won't enter energy fields, investors won't back energy investment, and major manufacturing and energy firms won't expand capacity if they can't be assured that their investments won't be rewarded over the long-term. Policymakers need to signal that it embraces not only access to conventional oil and gas resources but also the timely development required to bring them to market. Once this inventory of opportunity is clear, the market will respond as it always has to the challenge.

19) Is there something in the manufacturing sector that we need to do to help insure that you get the supplies that you need?

Policymakers need to signal long-term support for energy development of all kinds to provide the market with the confidence necessary to stimulate investment.

20) The International Energy Agency estimates that $22 trillion – in new energy investments will be needed by 2030. Where would that money come from?

We have not evaluated the IEA estimate and cannot comment on the amount, but agree that a lot of investment is needed. That investment will and is coming from companies like BP. Governments can play a roll in supporting investment, but it is companies that will make almost all of the expenditure. And, BP is doing more than its share of the investing.[1] *BP had capital expenditures of $19 billion in oil and gas globally. BP reinvested every dollar it made in the US right back into US operations to provide energy.*

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[1] BP represents 3% of global oil and gas. Of the IEA's $22 trillion estimate, $9.6 trillion is for oil and gas, which is about $400 billion a year. BP's capital expenditure in E&P and Refining last year was $19 billion or 5% of the IEA's estimate. BP is investing disproportionately more – by 70% – relative to its share of the market to increase energy supply.

21) What would be required to get biofuels to a commercial scale that they could replace oil in the United States?

> *BP does not believe that biofuels can replace oil in the US. We believe that development of non-food feedstocks, cellulosic technologies and improved molecules may allow biofuels to meet as much as 30% of the US transportation fuels needs by 2030.*

22) In your testimony, several of you point to speculation as a contributing cause of high crude oil prices. I have introduced legislation, the Prevent Unfair Manipulation of Prices (PUMP) Act (HR 594), which would improve oversight of "dark markets" which are currently unregulated by the Commodity Futures Trading Commission. In our December 2007 Oversight and Investigation Subcommittee hearing, we heard testimony that this could reduce the cost of oil by $30 a barrel. Do you believe that speculation in the market is driving up the price of oil? Would you support this legislation?

> *Regarding the role of speculation in the market, see our answer to Question 3. BP believes that the market oversight and enforcement powers exercised by the CFTC, as described in the April 3, 2008 testimony of Mr. Harris, are effective tools to protect the public from unlawful manipulation of prices. In addition, BP generally supports regulatory proposals that make the markets we trade in more efficient, more liquid and more transparent.*

23) What is the average number of barrels of oil your companies trade each day on NYMEX? On the InterContinental Exchange?

> *In 2008, BP's U.S. trading company has traded an average of 9.9 million barrels per day of Light Sweet Crude Oil contracts on NYMEX. This includes buys and sells, spread trading, and front month as well as future months contracts. The average daily total market volume of Light Sweet Crude Oil contracts on NYMEX for 2008 has been 558 million barrels per day.*
>
> *In 2008, BP's U.S. trading company has traded an average of 11.4 million barrels per day of WTI and Brent crude on ICE, which also includes buys and sells, spread trading, and front month as well as future months contracts. The average daily total market volume of WTI and Brent crude contracts on ICE for 2008 has been 504 million barrels per day.*

This data is competitively sensitive and BP requests that it not be disclosed to the public.

24) During the April 1, 2008 hearing, you each spent most of your time complaining about taxes, specifically that the Renewable Energy and Energy Conservation Tax Act (H.R. 5351) passed by

the House would repeal $18 billion over ten years in subsidies to your companies. Several times during the hearing, you also said that your companies do not support mandates and subsidies for renewable fuels. Over the next ten years, your companies are expected to make $14.6 trillion. H.R. 5351 would only account for approximately one tenth of one percent of your gross income! How can you insist on retaining these subsidies and tax breaks for your companies while opposing assistance for renewable energy?

> *BP supports the inclusion of renewable energy incentives in HR 5351, but we believe it is unfortunate that the funding source used is new taxes on the oil and gas industry. BP is committed to developing alternative energy and has recently increased its plans to nearly double its investment in the alternative energy business – and we believe that government support through tax incentives is critical to the viability of these energy resources. Imposing new taxes on the oil and natural gas industry to fund that goal, however, does not help supply the stable and affordable supplies of energy necessary to meet the needs of the US. BP supports a balanced energy policy that encourages development of alternative energy sources but also allows us to continue to responsibly develop our investments in all forms of energy in the US.*

25) At the American Society of Newspaper Editors Convention on April 14, 2005, the President said, "I will tell you, with $55 [a barrel] oil we don't need incentives to oil and gas companies to explore. There are plenty of incentives. What we need is to put a strategy in place that will help this country over time become less dependent. It's really important. It's an important part of our economic security, and it's an important part of our national security." Today, crude oil prices are double the President's example! Do you agree with President Bush that oil and gas companies do not need incentives to explore when oil is more than $55 a barrel? Do you agree with President Bush that we should instead be investing in renewable energy that will help this country become less dependent on oil?

> *We agree with the President that new incentives are not necessary to stimulate exploration and development for oil. Further, promoting the use of alternative energy resources is a worthy energy policy goal, but imposing new taxes on the oil and natural gas industry, as has been suggested, to fund that goal does not help supply the stable and affordable supplies of energy necessary to meet the needs of the United States. BP supports a balanced energy policy that encourages development of alternative energy sources but also allows us to continue to responsibly develop our investments in all forms of energy in the US.*

26) I have attached internal memos from Chevron, Texaco, and Mobil. The Chevron memo quotes a "senior energy analyst at the recent API convention," stating "if the US petroleum industry doesn't reduce its refining capacity it will never see any substantial increase" in profits. The Texaco memo complains that "supply significantly exceeds demand" leading to "very poor

refinery margins and very poor refinery financial results." The Mobil memo advocates keeping a smaller refiner, Powerine, from reopening, stating that a "full court press is warranted in this case." From 1995 to 2002, more than 30 refineries have been closed in the United States. Have any of your companies applied for permits to build new refineries? If yes, how long did it take to obtain the necessary permits? In July 2007, gas prices increased 30 cents overnight in Escanaba, Michigan. There were no supply disruptions or other major events that would influence the price this significantly. Is there any logical explanation why prices would increase 30 cents in that short of time? On May 23, 2007, the U.S. House of Representatives passed H.R. 1252, the Federal Energy Price Gouging Prevention Act by an overwhelming vote of 284 to 141. Please explain why this legislation is not needed, given the significant price increases consumers continue to face.

BP has not applied for any permits to build a new refinery since its predecessor company, Atlantic Richfield Company built its Cherry Point refinery in Washington State in the 1970s.

BP supports market based pricing that insures an adequate supply from local and global markets at all times. During times of emergency, it is important that supply can be moved to the areas that need it. We should not inhibit this.

BP is not opposed to price gouging legislation that prohibits excessive charges for essential goods during periods of declared disaster, where excessive charges are defined as prices significantly higher than competitive sellers are charging in the same general geographic area for the same goods and take into account increased cost due to the disaster and the seller's prices prior to the disaster. It is further BP's policy that all existing price gouging laws be strictly observed.

The majority of BP's branded gasoline is distributed by independent business people -- franchisees, dealers, or jobbers. BP cannot set the retail price for these independent business people. If a court of law determines that one of these distributors violated any price gouging laws, then BP can act to discipline it. BP does not price gouge at its company owned and operated sites.

27) In May 2004, the U.S. General Accounting Office released its report, "Effects of Mergers and Market Concentration in the U.S. Petroleum Industry." In this report, GAO found that over 2,600 mergers have occurred in the U.S. petroleum industry since 1990. The GAO also pointed to economic literature that suggests that firms sometimes merged to enhance their ability to control prices. Each of your companies today is the result of significant mergers in the industry. Do you see any more mergers taking place?

BP agrees with the Federal Trade Commission that the GAO report should not be relied upon in making policy. As stated by the FTC:

> *The GAO report still contains major methodological mistakes that make its quantitative analyses wholly unreliable. It relies on critical factual assumptions that are both unstated and unjustified, and it presents conclusions that lack a quantitative foundation. Simply stated, the GAO report is fundamentally flawed.*[2]

Even if you take the conclusions of the GAO Report at face value, the GAO concluded that two of the transactions studied led to decreases in wholesale prices and the results from one of the transactions was inconclusive. This suggests that in at least some cases, integration can lead to lower prices. In the absence of any clear metric as to which transactions will lead to lower prices and which will lead to higher prices, any disincentive for further integration has the potential to lead to economic inefficiencies and higher costs for consumers.

As to consolidation and concentration in the market place, consolidation has allowed BP to compete in this global environment. Even after mergers such as BP's, the FTC has determined that the U.S. domestic oil and natural gas industry remains highly competitive, highly regulated and unconcentrated because retail gasoline is sold largely through independent dealers who face stiff competition.

The price of gasoline is largely dependent on the price of crude oil. And, current sources of crude oil are expensive and challenging to obtain. In the last five years, BP has invested more than $30 billion dollars into energy investments in the United States. BP's size and scale allows the company to continue to increase both its crude oil production and long-term reserve base in the United States, while also investing in new alternative and renewable energy technologies.

BP's consolidation with Amoco and ARCO has allowed significant investment into its facilities and infrastructure at approximately $700 million a year. Finding and producing oil and gas today requires greater scale to meet the challenges posed by greater technical, logistical, financial and permitting hurdles. For example, BP is currently working with others to invest in a pipeline to bring Alaska natural gas to consumers in the US Midwest.

BP is also using investment to find new oil and gas reserves in the deep water Gulf of Mexico; this exploration would most likely have overwhelmed a smaller company. These projects are extreme in every way – extremely risky, extremely large, extremely deep and extremely costly – and present unprecedented technical challenges.

Finally, BP remains a small player in this global business. Foreign national oil companies control more than 50 percent of global oil and gas production and

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[2] Prepared Statement of the Federal Trade Commission titled "Market Forces, Anticompetitive Activity, and Gasoline Prices: FTC Initiatives to Protect Competitive Markets, presented by William E. Kovacic, General Counsel, Before The Subcommittee on Energy Policy, Natural Resources and Regulatory Affairs Committee on Government Reform United States House of Representatives (July 7, 2004) at 8.

more than 80 percent of the world's oil and gas reserves. By comparison, BP represented roughly 3 percent of global oil and gas production, and less than one percent of global oil and gas reserves.

It is impossible for BP to predict whether any further consolidation is contemplated among its competitors.

28) In your testimony, almost all of you mention "more domestic drilling" as your top solution to high energy prices. What assurance can you provide that oil and gas from the Arctic National Wildlife Refuge (ANWR), the Outer Continental Shelf (OCS), or other domestic sources would stay in the United States? What is your response to economists that tell us that the oil and gas will likely go to higher priced markets in Japan and elsewhere?

The export of crude oil to any destination requires a license from the Department of Commerce (see the provisions of 15 CFR Part 754 Short Supply Controls). Energy is traded on global markets. In general, increasing the supply, wherever sourced, of oil and gas can be expected to have downward pressure on prices. It is not advisable to interfere with supply and demand and liquidity by artificially restricting where energy commodities can be sold. Such artificial restrictions can cause price dislocations and disincentives to increased production.

29) In May 2006, the Energy and Commerce Committee held a hearing on gas prices, and we discussed the crack spread, or the difference between a barrel of crude oil and the refined product. At this hearing, the average crack spread for a refinery in 2006 was estimated to be about $20 to $30 a barrel by Howard Gruenspect, the Deputy Administrator at the Energy Information Administration. Mr. Gruenspect testified that a crack spread of $8 or $9 is sufficient to cover refining expenses and provide a reasonable profit to the facility. What is your current crack spread at the refineries your companies operate? Why have your companies scaled back their refinery expansion plans to keep crack spreads high?

The crack spread at a refinery references the cost of crude used at a refinery as compared to the market price for the refined petroleum products - it is often also referred to as a refining margin. The crack spread necessarily changes based on the market price of crude oil and refined products; these market prices are set by supply and demand. Crude properties vary as does the ability of different refineries to efficiently crack the crude to produce refined product. The various crudes have different prices and so BP publishes a Global Indicator Refining Margin (GIM). The GIM is defined in BP's March 2008 20-f at page 26 and was $9.94 per barrel.

BP has not scaled back refinery expansion to keep crack spreads high. In fact, BP intends to spend more than $5 billion at its Whiting and Toledo refineries to increase capacity at each plant.

30) Please provide a list of oil and gas leases currently in the possession of your company and its subsidiaries, and give a status report as to the state of the production of each of these leases.

The following outlines BP lease maintenance practices and federal leases held by BP in the US.

BP lease maintenance practices

- *BP has no "inactive leases," are all under active review – seismic (acquisition, processing), or drilling (exploration or appraisal).*
- *BP continuously manages its federal lease portfolio to determine if we have the appropriate activity underway and if we want to continue to pursue prospects.*
- *If we decide not to pursue a prospect on a federal lease, our options are to:*
    - *make the acreage available to others in industry (sale/farm-out);*
    - *relinquish leases to the US Government.*

Gulf of Mexico/Offshore Federal Leases

In 2007, BP had an interest in 704 federal leases in the Gulf of Mexico—the Outer Continental Shelf and in Deep Water (>1200 feet). Of that total:

- *124 leases are producing or are under active development.*
- *459 leases are in the exploration phase. BP is currently working these leases through its 'prospect maturation process,' where seismic programs are being developed; data is being acquired, processed, reprocessed; or prospects are under active exploration/appraisal drilling.*
- *37 leases were relinquished to MMS.*
- *84 leases were assigned, in part or in whole, to a third party, or expired.*
- *Over the period from 2000 to 2007, in the Gulf of Mexico, we either made available to industry or returned to MMS an average of 75 federal leases per year.*
- *Over the next five years 200 of BP's current federal leases in the Gulf of Mexico will expire if we, or others, choose not to pursue them further.*

Onshore (lower 48) Federal Leases

Of the approximate half million federal net acres (708 leases) held by BP, onshore, in the Lower 48, only about 5% of the total net acres (~40 leases) are still within their primary terms, meaning they are under review for possible development, sale or relinquishment. The other 95% of the federal acres are held by production. Most of BP's activity onshore focuses on active development drilling of this existing acreage which is held by production.

Alaska Federal Outer Continental Shelf (OCS) Leases

BP has six federal OCS leases in Alaska.

- *Three leases in the Northstar Unit are held by production.*
- *Three federal leases are associated with the Liberty Unit. We expect to begin drilling the first production well in 2010 and anticipate first oil production in 2011.*

31) As fuel prices rose over the past 6 years, has American demand decreased? Why or why not has this occurred? If gas taxes were increased, do you think demand would decrease? Did this happen in European countries when then imposed large gas taxes?

Yes, US demand is now declining: May 2008 consumption was 1.1% lower than a year ago. This is an economic response to higher prices. Increasing the price further with a tax would likely contribute to consumption being lower than it would otherwise be. Petroleum taxes in Europe increased after the oil shocks of the 1970s. Since 1990, European oil demand increased by 0.5% a year on average compared to 1.2% p.a. in the US. However, economic and population growth, key drivers of energy consumption, have also been lower in Europe.

32) At current projections, when will your current reserves be depleted?

At 2007 average rates of production, BP's year-end reserves for oil and gas would last 11 years and 15 years respectively. However, BP has a track record over the last 10 years of adding to its reserve base each year through investment in exploration and development.

33) When do you expect underdeveloped countries will reach a level to where they will begin to significantly buy oil for use? How will this affect supply and fuel prices?

Consumption from developing countries is already significant; it constitutes 40% of the global oil market. Recent oil consumption growth has been largely concentrated in developing countries. While OECD demand fell by 390 kb/d in 2007, consumption in developing countries grew by 1.4 Mb/d. The moderating effect of high prices, which in the developed world is reducing consumption, is being overwhelmed in developing countries by rapid economic growth, industrialization, price subsidies and rising populations.

34) If all conventional, alternative, and unconventional sources of oil in the U.S. were to be developed, how long would the supply last based on current estimates of increased usage?

We do not know. We track global proven reserves in the BP Statistical Review of World Energy (www.bp.com/statisticalreview), *where conventional US proven reserves would last 12 years based on current rates of production. The US data comes from EIA* (http://www.eia.doe.gov/oil_gas/natural_gas/data_publications/crude_oil_natural_gas_reserves/cr.html). *It does not include undiscovered oil, potential recovery rate improvement, or unconventional resources.*

More reserves are discovered and added to proven reserves every year. For the world as a whole, the reserves to production ratio has remained near 40 years for a long time despite growing annual production. How much conventional oil is ultimately recoverable or alternatives/unconventional produceable is determined by changing commercial, technical, and legal conditions. Also, significant promising acreage in the OCS and Alaska have not been explored, at least not with modern technology and equipment, so we cannot say how much is there. In addition, on consumption, it is by no means certain that it will always rise. In *fact, consumption has been falling in 2008 and could fall further depending on economic conditions, as people purchase more efficient cars, or if a carbon price is instituted, etc. A carbon price could also affect the production of unconventional resources, some of which are carbon intensive.*

35) Please describe to this committee your short, middle, and long-term plans for oil and renewable energy development.

BP expects to spend $30 billion over the next five years to maintain production of natural gas from the Rocky Mountains, to renew critical infrastructure in Alaska, to continue development of the deepwater Gulf of Mexico, to increase gasoline production from Midwest refineries, double the capacity of our integrated solar manufacturing plant and aggressively develop our 15 gigawatt wind portfolio. BP is investing in a portfolio of options to increase energy production both now and into the future. Because of the scale and complexity of our investments, their timing and impact will be felt across a 10-15 year planning cycle. The partial list below provides an indication of scope of our investments and the expected timing of their completion:

Energy Biosciences Institute - $500 million (1-10 years)
The institute is a joint collaboration with the University of California Berkeley, University of Illinois – Urbana Champaign and the Lawrence Berkeley National Lab. The project will look at the entire biofuels value chain – from feedstock to enzymes to process and on through to advanced biofuels molecules.

Colorado Natural Gas - $2.4 billion (13 years)
Increase ultimate recovery of coalbed natural gas from the San Juan Basin of southwestern Colorado by an estimated 1.9 trillion cubic feet. The 13-year development program would increase current BP net production of 425 million cubic feet per day by more than 20 percent, and maintain production above present levels for more than a decade.

Whiting refinery modernization - $3.8 billion (3-4 years)
Upgrade and expand the Whiting refinery to increase Canadian heavy crude oil processing capability by about 260,000 barrels per day. The project also has the potential to increase motor fuels production by about 15 percent, or about 1.7 million additional gallons of gasoline and diesel per day.

Wind Power - $700 million (1-2 years)
BP and its partners invested about $700 million in 2007 to develop wind capacity throughout the US, including California, Colorado and Texas. During 2008, BP will construct 5 US wind farms with a total generating capacity of 700 MW and a total value of over $1.5 Billion. This will bring our total installed capacity of wind generation to over 1,000 MW by the end of 2008. By 2010, we expect to have 2,400 MW installed. This is enough power to meet the needs of 720,000 households.

Solar Manufacturing Expansion - $97 million (1 year)

BP is expanding the BP Solar manufacturing facility in Maryland, nearly doubling its capacity. When completed in 2009 the plant will have a manufacturing capacity of 150 MW in its casting and sizing processes.

Deepwater Gulf of Mexico - $20 billion (1-10 years)
BP is increasing exploration and production of oil and gas from deepwater reservoirs in the U.S. Gulf of Mexico. BP will continue development plans to explore new lease area and bring producing areas on-line. BP's Atlantis platform just began production at the end of 2007 and our Thunderhorse platform will begin production by the end of 2008. At capacity, these platforms will supply an incremental 400,000 bbl/day of oil.

Alaska renewal - $685 million (ongoing)
BP is investing hundreds of millions of dollars in Alaska each year to commercialize and produce the billions of barrels of known oil resources in our Alaska portfolio. We have enough known oil and gas resources to sustain production for the next 50 years but this will require billions of dollars in new investments.

Wyoming Natural Gas - $2.2 billion (1-15 years)
Over the next 15 years BP will double our natural gas production in Wyoming. Several hundred new wells are planned in the Wamsutter Field, BP's largest onshore development drilling program.

Husky Energy Joint Venture – $5.5 billion (5-7 years)
BP and Husky will jointly develop Canadian oil sands resource and upgrade and modernize BP's Toledo, OH refinery. When fully operational the project is expected to deliver an incremental 200,000 bpd of oil to the US market and allow Toledo to produce 600,000 gpd more product to Midwest consumers.

Denali – The Alaska Gas Pipeline - $30+ billion (10 years)
BP and ConocoPhillips have launched this project to bring 4 Bcf of Alaska gas to markets in the lower 48 states. The project is expected to cost in excess of $30 billion and will be the largest private sector construction project ever built. Near term spending will be to advance the project to an open season within the next 36 months.

36) Please provide the Committee with any and all documents related to BP's participation in Vice President Cheney's energy task force.

Please see the attached pdf files for the material provided to A. Lundquist on VP Cheney's staff for consideration in the drafting of the Administration's energy policy.

37) On Page 7 of your testimony, you say "As we look to the future, the US investment climate is deteriorating" and that "stumbling blocks exist across the energy profile and are not just confined to oil and gas activities." Could you tell us what you think the biggest causes of the investment problem and what kind of ripple effect we can expect to see in our economy?

There is no single policy option that applies equally to the development of all energy sources. However, there are several overriding principles that are essential to every investment decision – fiscal, legal and regulatory certainty. Uncertainty in any one of these areas increases project risk and ultimately leads to higher development costs. For this reason, policymakers should go to great lengths to create a long-term, stable energy policy that will provide the proper confidence and guidance for investors to make the huge investments necessary to supply the nation's growing energy needs into the future.

An example of one such policy is the need to create a national climate change framework. Absent this policy, energy providers, power producers, manufacturers and consumers won't have the ability to adequately price carbon and make the necessary investments and operational changes required to reduce the potential impacts of climate change. Furthermore, existing laws (Clean Air Act, Endangered Species Act) are being used by NGOs and others as surrogates for climate policy. These laws are not well suited for this purpose and could significantly curtail needed energy investment in the US.

38) What do you see as the most interesting prospect for non-food biofuel production?

BP's $500 million investment in the Energy Biosciences Institute (EBI) will research alternative feedstocks, enzymes and processes for the manufacture of biofuels. Early results suggest that an energy grass called miscanthus holds great promise. Our EBI partner, University of Illinois – Urbana Champaign has been studying miscanthus for several years. It is a low-input, fast growing, high yielding crop that can deliver up to 3 times the amount of biofuel per acre as conventional corn-based ethanol. More work is necessary to further unlock this potential but we are confident that the EBI work will deliver a commercial application in next several years.

39) On Page 8 of your testimony, you say "Our nation, with 5% of the world's population, demands 25% of the daily world production. I don't think this is sustainable." What do you think the best policy is for sustainable development of our oil and gas resources?

Policies that allow for the continued development of all US energy resources (oil, gas, coal, nuclear, wind, solar, biofuels, alternatives) are essential to meeting the future energy needs of US consumers. There is no single energy source that is capable of supplying US energy needs. It will take a portfolio of options including access to resources, legal and regulatory certainty, economy-wide carbon price and transitional incentives to enable resources of all types to be adequately developed.

40) On Page 8 of your written statement, you note the non-financial opportunities that you think would be effective in stimulating additional investment. What do you think the most important non- financial opportunities are for all areas of energy development?

There is no single policy option that applies equally to the development of all energy sources. However, there are several overriding principles that are essential to every investment decision – fiscal, legal and regulatory certainty. Uncertainty in any one of *these areas increases project risk and ultimately leads to higher development costs. For this reason, policymakers should go to great lengths to create a long-term, stable energy policy that will provide the proper confidence and guidance for investors to make the huge investments necessary to supply the nation's growing energy needs into the future. An example of one such policy is the need to create a national climate control framework. Absent this policy, energy providers, power producers, manufacturers and consumers won't have the ability to adequately price carbon and make the necessary investments and operational changes required to reduce the potential impacts of climate change.*

41) On Page 9 of your testimony, you note that if biofuel producers can't supply and if bio-fuel manufacturers can't produce – it is the fuel retailers that will pay the penalty – have you estimated how much this scenario could increase the cost of fuel for the consumer?

The penalty is nominally based on the price differential between gasoline and ethanol prices, not to be less than $0.25/gallon.

42) In your opinion, does the US have an energy policy that forces oil and gas companies to seek foreign resources while at the same time politicians complain about how much foreign oil we import? What do you think the right policy is to increase domestic production?

Energy infrastructure development relies upon the ability to explore and develop a resource base. Thus, having access to resources provides confidence to the marketplace to invest for the long-term development opportunities. Energy investment lagged for nearly a decade beginning in the mid-1980's largely due to low energy prices and restricted opportunities. Energy hiring stalled, skilled workers redeployed, interest in technical study at universities lagged and manufacturing capability went overseas. These trends take years to reverse and concerted policy support to correct. Thus a clear, comprehensive, long-term approach to energy development is necessary to provide the proper signal to stimulate increased productive capacity.

43) You note on Page 12 of your testimony that many countries subsidize prices in their domestic energy markets – what notable countries have such practices and how would that compare to so-called US oil subsidies?

The subsidies I referred to on page 12 are consumer subsidies. Many oil exporting countries have such subsidies which reduce the amount individual consumers pay for energy. The highest rates of subsidies tend to be found in oil exporting countries, like OPEC members including Venezuela and Iran. Many rapidly-developing oil-importing Asian countries also have consumer subsidies, though they have been reducing the amount of subsidies in 2008 as their fiscal burden or distortionary effects increase, examples include China and India. The US has no similar consumer subsidies for oil and gas.

44) On Monday, March 31, 2008, litigation was settled with the result that Delaware can deny BP the ability to build the Crown Landing LNG terminal. What federal/state regulations are needed to mitigate such issues?

BP was disappointed in the Supreme Court's decision, however, it is important to note, while the Supreme Court's decision allows Delaware to block the construction of an LNG unloading pier in Delaware waters as initially proposed, it does not allow Delaware to block the construction of the facility on New Jersey's shore. Therefore, BP is committed and continues to evaluate its options to construct the Crown Landing terminal and pier project.

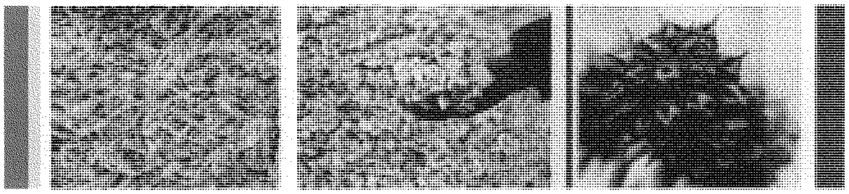
Any LNG project applicant seeks statutory and regulatory certainty throughout the process. The statutory and regulatory framework, both on the Federal and State levels, must provide a clear and predictable path forward for the applicant so that if the applicant is aggrieved by a particular action by a governmental agency, the applicant can have the matter ultimately resolved in a timely manner and not face the uncertainty of seemingly endless delays in rendering a decision by either the agencies or the courts. Ultimately, the US needs one federal agency, with final authority, that takes into consideration the national interest and input from state and local, and determines whether or not these energy infrastructure projects are in the public interest.

45) Mr. Malone (BP), in your testimony you mentioned the Whiting, Indiana refinery modernization as one of BP's major investments. I was one of several Great Lakes members that raised concerns after BP convinced the Indiana Department of Environmental Management to allow BP to dump an additional 1,584 pounds of ammonia, an increase of 54 percent; and an additional 4,925 pounds of suspended solids, an increase of 35 percent, into the lake each day. With record profits, why do you have to pollute the Great Lakes as you refine oil?

BP continuously strives to run its operations against the standard of "do no harm to the environment." This practice requires BP and its operators to rely upon the laws, regulations and standards passed and adopted by policymakers at the Federal and State level. The original Whiting refinery water discharge permit met all State and Federal requirements and with the exception of the amounts for ammonia and suspended solids, at levels at or below the previous permit limits. However, because of community and policymaker concerns we agreed to limit our discharge levels of ammonia and suspended solids to the previously permitted levels as well. We are confident that we will be able to apply new technology in a way to minimize these discharge levels but this commitment does pose a risk to the viability of the Whiting refinery upgrade.

Policymakers rightfully ask and expect the industry to make the investments necessary to supply the growing energy needs of the consuming public. BP has responded by investing its profits dollar for dollar in energy projects in the US. It is our hope and expectation that policymakers will stand-by the laws and regulations it enacts so that industry has the certainty it needs to support these investments.

Chevron Biofuels Research Collaborations



Chevron Technology Ventures

Bringing Cellulosic Biofuels to Large-Scale Commercial Production: Partnership is Key.

The scientific, technical, and logistical challenges of bringing cellulosic biofuels to large-scale commercial production are too large for any one organization or industry to tackle alone.

A strong, sustainable biofuels industry can emerge only through the combined efforts of industry, university and national laboratories, and governments. That's why Chevron has formed strategic research alliances with leading organizations in each of these groups.

Catchlight Energy LLC

In February 2008, Chevron and Weyerhaeuser Co., one of the nation's largest forest products companies, formed a 50-50 joint venture – Catchlight Energy LLC – to develop the next generation of renewable transportation fuels from nonfood sources.

Catchlight's initial focus is developing and demonstrating novel technologies for converting cellulose and lignin from a variety of sources into economical, low-carbon biofuels. The venture leverages Chevron's technology capabilities in molecular conversion, product engineering, advanced fuel manufacturing, and fuels distribution with Weyerhaeuser's expertise in collection and transformation of cellulosics into engineered materials, land stewardship, crop management, biomass conversion, and capacity to deliver sustainable cellulose-based material at scale.

National Renewable Energy Laboratory (NREL)

In September 2006, Chevron Technology Ventures (CTV) entered into a five-year agreement with NREL to research and develop new production technologies for biofuels. Researchers from CTV and NREL are collaborating on projects to develop the next generation of process technologies that will convert cellulosic biomass, such as forestry and agricultural wastes, into biofuels such as ethanol and renewable diesel. They are also working to identify and develop algae strains that can be economically harvested and processed into finished transportation fuels such as jet fuel.

Georgia Institute of Technology

In June 2006, CTV and the Georgia Institute of Technology formed a strategic research alliance to pursue advanced technology aimed at making cellulosic biofuels and hydrogen viable transportation fuels. Chevron will contribute up to $10 million over five years for research into and development of these emerging energy technologies.

The alliance is focusing its research on four areas: production of cellulosic biofuels, understanding the characteristics of biofuel feedstocks, developing regenerative sorbents and improving sorbents used to produce high-purity hydrogen. (During hydrogen production, sorbent materials are used to remove gases such as carbon monoxide, carbon dioxide, and nitrogen.)

Another focus area is understanding the characteristics of biofuels produced from different feedstocks and their effects on biofuel production processes. Defining the properties of various biofuels will help in the design of equipment and procedures to accommodate different feedstocks.

University of California at Davis

In September 2006, CTV and UC Davis executed a five-year research agreement for collaborative R&D directed at the development of technology for production of liquid transportation fuels from biomass feedstocks. Chevron will contribute up to $25 million over five years for research into and development of these emerging energy technologies.

The objective of the Chevron-UC Davis research is to develop commercially viable processes for the production of transportation fuels from renewable resources such as new energy crops, forest and agricultural residues, and municipal solid waste. The collaboration calls for research in biochemical and thermochemical conversion, as well as a demonstration facility to test the commercial readiness of these technologies.

Chevron and UC Davis formed the collaboration because their research and development goals related to emerging energy technologies are closely aligned.

The collaboration is expected to focus its research on four areas:

- Understanding the characteristics of current California biofuel feedstocks;
- Developing additional feedstocks optimized for features such as drought tolerance, minimal land requirements, and harvesting technology;
- Production of cellulosic biofuels;
- Design and construction of a demonstration facility for biochemical and thermochemical production processes.

Texas A&M University

In May 2007, CTV and the Texas A&M Agriculture and Engineering BioEnergy Alliance (Texas A&M BioEnergy Alliance) announced a strategic research agreement to accelerate the production and conversion of crops for manufacturing ethanol and other biofuels from cellulose. Over a four-year period, CTV will support research initiatives that will focus on several technology advancements to produce biofuels including:

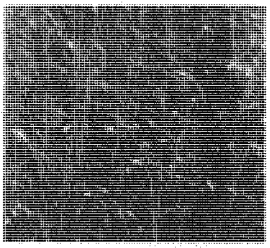
- Identifying, assessing, cultivating, and optimizing production of second-generation energy feedstocks for cellulose and bio-oils with a focus on non-food crops;
- Characterizing and optimizing the design of dedicated bioenergy crops through advances in genomic sciences and plant breeding;
- Developing integrated logistics systems associated with the harvest, transport, storage, and conversion of bioenergy crops;
- Developing advanced biofuels processing technologies.

Colorado Center for Biorefining and Biofuels

Chevron is a founding corporate member of the Colorado Center for Biorefining and Biofuels (C2B2). The research focus of the center is on the identification of biomass energy crops and the development of advanced conversion technologies. Participating research institutions in C2B2 include the University of Colorado at Boulder, Colorado School of Mines, Colorado State University and NREL.

Chevron's Biofuels Research and Development Objectives:

- Identify, assess, cultivate, and optimize production of energy feedstocks for cellulose and bio-oils, with a focus on nonfood crops.
- Characterize and optimize the design of dedicated bioenergy crops through advances in genomic sciences and plant breeding.
- Create integrated logistics systems for the harvest, transport, storage, and conversion of bioenergy crops.
- Develop advanced biofuels processing technologies.



Chevron

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Chevron Technology Ventures, a division of Chevron U.S.A. Inc. identifies, develops and commercializes emerging technologies and new energy systems.

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April 17, 2001

Mr. Andrew Lundquist
Director
National Energy Policy Development Group
Vice President's Office
281 Old Executive Office Building
17th Street and Pennsylvania Avenue, NW
Washington, DC 20504

Dear Andrew:

It was good to see you again the other day, and I promised to revert with some more specific ideas as you finalize the task force energy framework.

Natural Gas

Firstly, it seems that it would be very powerful for the administration to make the point that the overall energy policy is better for the environment than the prior situation. The key to this is gas – it is much cleaner than any of the options, and to the extent that the policy positively encourages gas use and production, you will be able to make this important claim. You mentioned that there is some concern over the long term gas supply situation, and Attachment 1 contains some data which I think you might find helpful in understanding our view of the long and short-term gas supply situation. In short, we believe we are now beginning to see supply side responses to recently increased drilling. Getting the gas into the U.S., and transporting it, can be assisted as noted below.

Some specific measures would be helpful to encourage the supply into the U.S., and the transportation of gas around the U.S. Increased gas imports also helps in energy security for the U.S., since we believe the security is related directly to the diversity of sources. There are two specific areas to look at:

a) LNG

There is a need to facilitate investment into LNG import terminals. If LNG regasification facilities were treated as equivalent to processing facilities, consistent with their production-related function and, therefore, not regulated as a jurisiticional facility under NGA Section 7, investment would be facilitated. As you know, we, and others, are considering investment into regasification facilities.

in order to import LNG into the country. Our estimates suggest up to 3bcf/day of incremental LNG supply into the U.S. could be facilitated with the right policy incentives. Additional detail is contained in Attachment 2.

b) **Pipeline Allocation and Rate Making Policies**
To facilitate efficient investments in infrastructure, a number of changes would be proposed to existing allocation and rate-making procedures as summarized in Attachment 3.

Fuels
With respect to fuels and the distribution around the United States, it is clear we need to move toward a more fungible system to reduce price volatility. As a general principle, policy actions should mandate the required outcome, rather than the specific chemistry as is currently the case. RFG currently presents an issue with regard to the oxygen mandate; it is possible there will be multiple requests for oxygen waivers from individual states as they seek to ban MTBE. This situation will get complex, and cries out for federal pre-emptive action.

Strictly, our view is that we don't actually need oxygenates in gasoline at all. To the extent that they are mandated for whatever reason, the industry should be phasing out MTBE. That leaves ethanol. Ideally, if the objective is to encourage ethanol production, this should be handled under the right statute. That may be politically infeasible, but to the extent that it is mandated in gasoline, this must be done under a national pooling and trading program if gasoline price volatility is not to be increased.

This recommendation will improve the fungibility of the gasoline system and, in any event, is a clear answer to a problem which seems inevitable without some federal action.

Renewables
You also asked for some ideas about how to encourage renewables without offering specific tax breaks. Two particular suggestions come to mind:

a) Net Metering Nationwide
Implement net metering systems in all states to allow distributed power systems to be connected to the power grid. This would increase the incentive for consumers to implement a variety of distributed power systems.

b) Facilitate and Promote Incentives for Residential Solar Energy Systems
Where state funded programs have been implemented, demand for residential solar power systems has increased dramatically – a $3.00 per watt subsidy direct to the consumer is the approximate order of magnitude.

Fiscal

Lastly, we talked about direct tax incentives. Clearly, one must tread carefully here, but it might be helpful to outline some specifics to the extent that they would have positive and measurable impact on production.

- Extending Section 29 credit to new wells will clearly encourage drilling and enhance production.

- Extending Section 29 relief to cover heavy oil would result in specific actions in Alaska to increase production. Our estimates are that 60-70MBD could be facilitated in the near term.

As you noted, this would have to be specific and measurable, but I have no doubt the industry could provide such specifics.

As a principle we prefer the use of market forces, development of competition, and light handed regulation, using traditional regulation only when monopoly market power exists.

We also talked about technology and NSR. I have sent these under separate cover and hope that they are useful to your deliberations. I will also send you our current ideas on climate change, along with biographies for Charles Nicholson and Jeff Morgheim as discussed.

I hope we've pitched these recommendations with sufficient specificity to be helpful to you.

I look forward to seeing you soon.

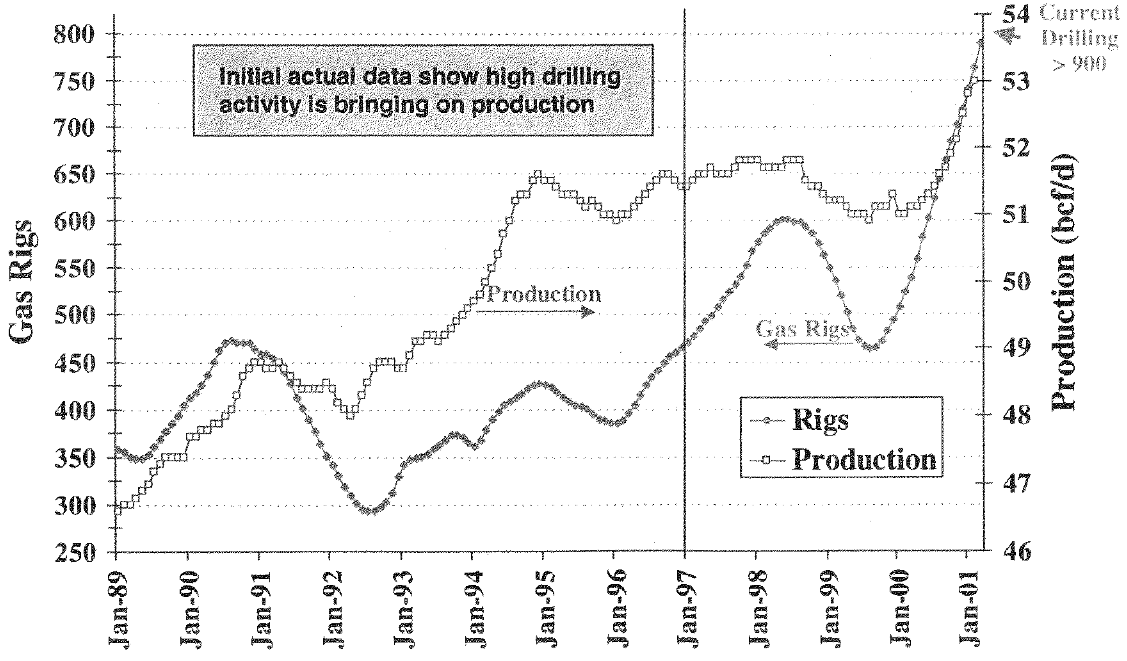
Sincerely,

JAM/jw

Attachments

U.S. drilling/production

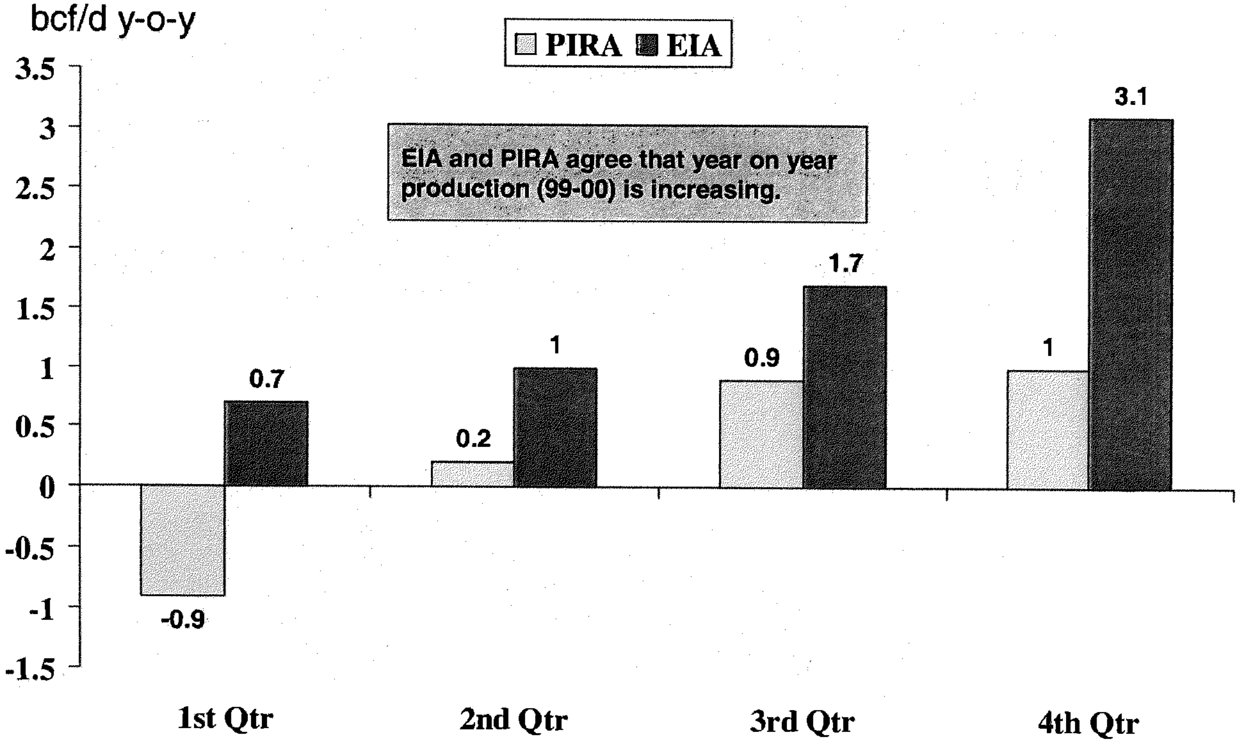
12 Month Averages



Initial actual data show high drilling activity is bringing on production

Source: EIA

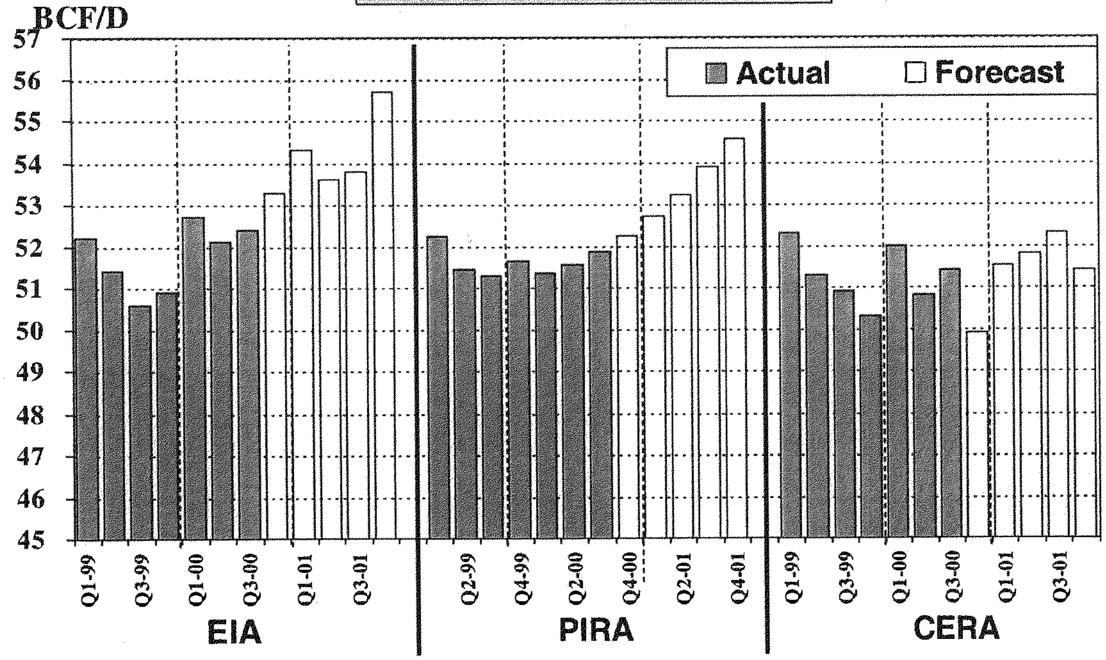
US gas production 2000 - latest Q4 estimates



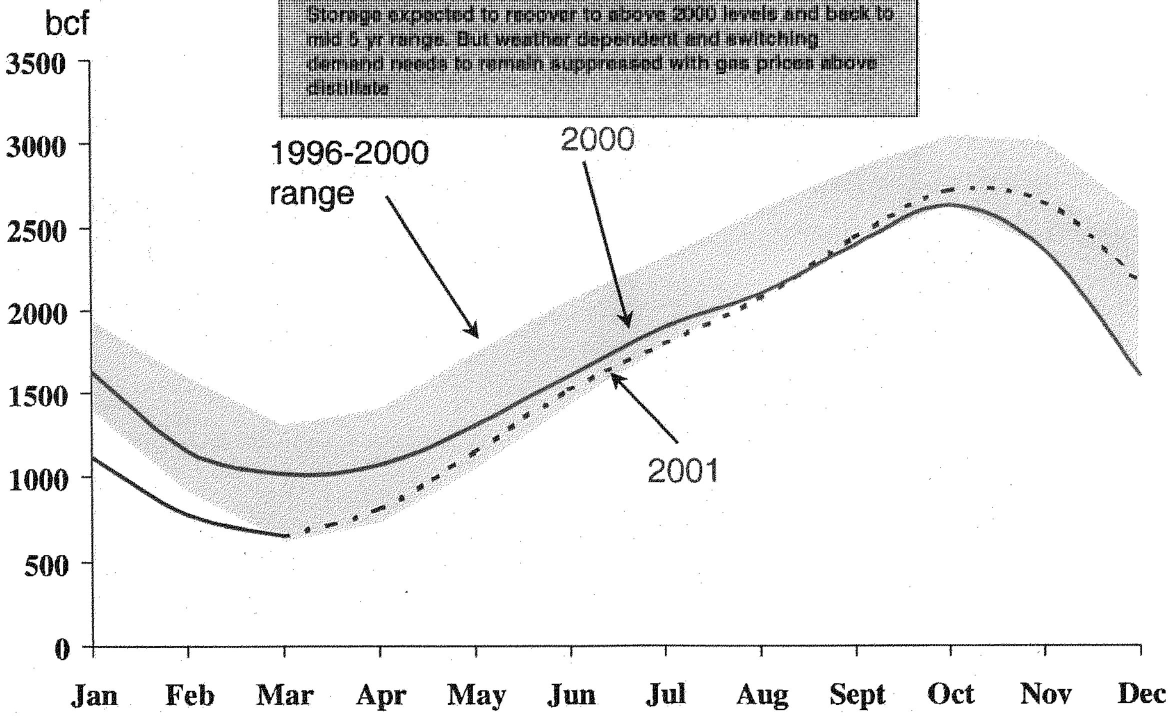
EIA and PIRA agree that year on year production (99-00) is increasing.

Production forecasts

Forecasts vary, but indicate 2001 general trend continues upward



Working storage at month end – US total

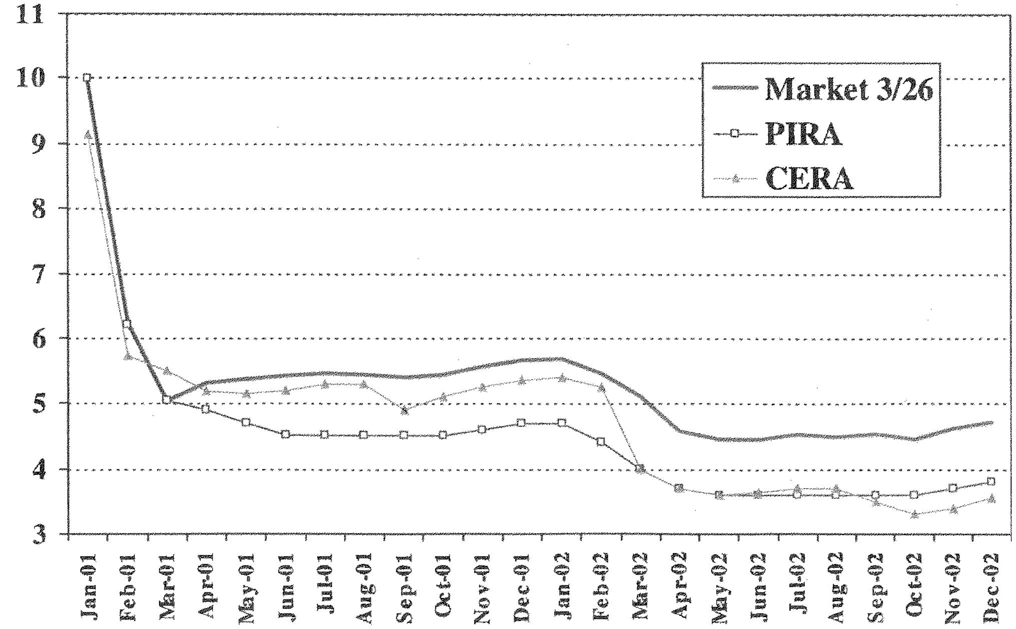


Storage expected to recover to above 2000 levels and back to mid 5 yr range. But weather dependent and switching demand needs to remain suppressed with gas prices above distillate

Source : PIRA Apr2001

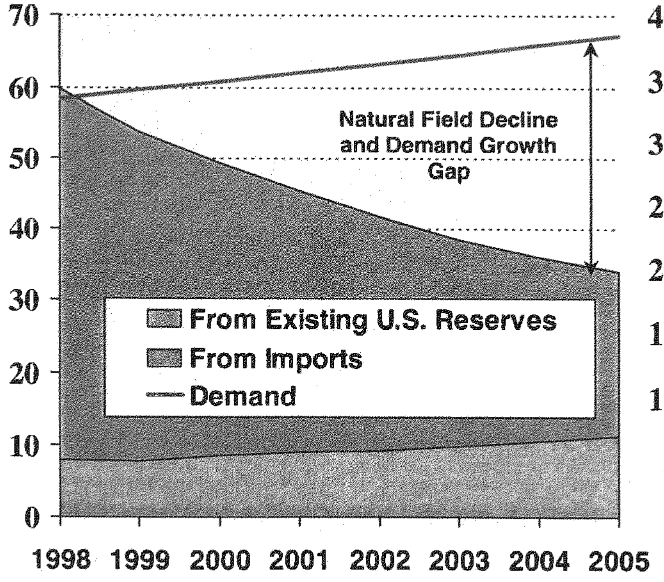
Henry Hub price outlooks

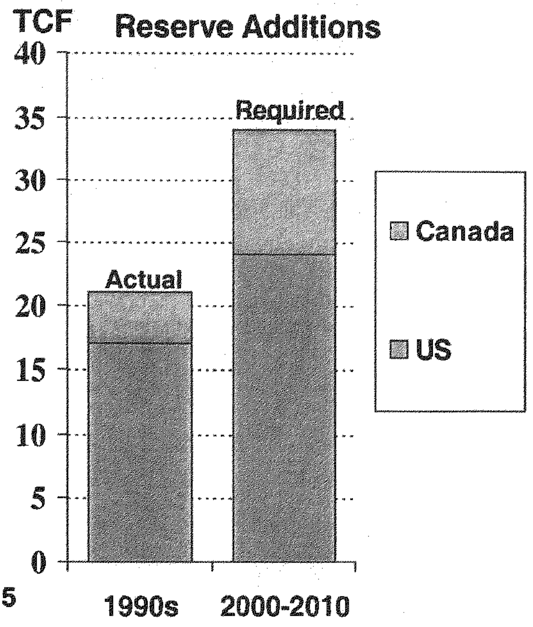
The price response has worked. With continued production growth and storage recovery, market sees lower price platform circa. Q1 2002



U.S. long term supply and demand

- Each year 7-8 bcf/d of deliverability must be added - 1 for demand growth, 6/7 to replace declines
- At constant R/P ratio, North America must replace 120% of production to meet a 2% demand growth
- Sufficient supply exists and industry is confident of its ability to develop them

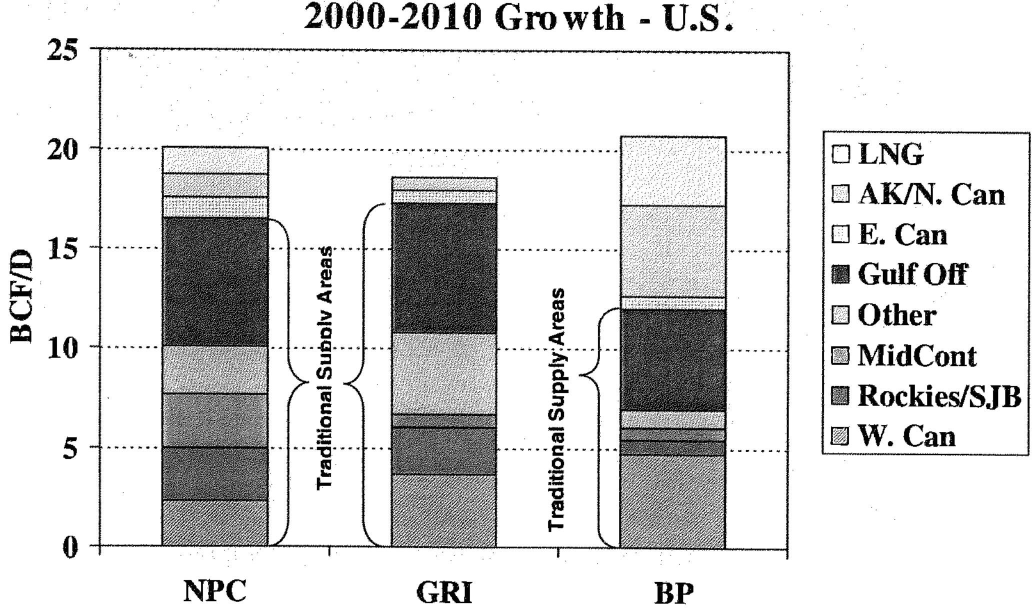




Source: Various

Supply growth forecasts

- Consensus around growth, but divergence on source location.
- BP view is that 'frontier gas' – LNG, Alaska, E. Canada – are key to underpin supply growth needed to meet longer term demand expectations



Attachment 2

Policy to Encourage International Production and Importation of Liquefied Natural Gas (LNG)

Summary of Proposed Policy

The construction of new LNG import terminals is needed in the U.S. to help meet the growing demand for natural gas. A sound national energy policy should encourage producers of LNG to construct new LNG terminals in the U.S. To accomplish this goal, two specific policy initiatives are key:

- Allow the capacity at new LNG import terminals constructed by LNG producers to be utilized by the LNG producer, as needed, for its LNG supply.
- Expedite permitting by FERC and other governmental agencies having jurisdiction, by simplifying the process and appropriating sufficient personnel and other resources to these agencies.

Proprietary Use of Terminal Capacity by LNG Producers/Terminal Owners

FERC has historically invoked the Natural Gas Act (NGA) to regulate LNG terminals under:

a) NGA Section 7 relating to construction of facilities used to transport gas in interstate commerce, and

b) NGA Section 3 relating to construction, operation and siting of facilities used to import or export gas from foreign countries.

Existing LNG terminals, the majority of which are owned and operated by pipeline companies, have been, or are expected to be, operated under open access regulations appropriate to their status and function as pipeline-owned and operated extensions of the pipeline system. While pipeline companies are likely to look with continuing interest toward the development of new LNG terminals, it will be important to implement policies that also will encourage LNG producers to invest in and operate such facilities. The existing idle LNG import capacity built in the 1970's is now fully contracted with deliveries expected to commence by mid-2002. It is expected that up to 3 BCF per day of incremental LNG supply can be delivered to the U.S. market by 2010 with the appropriate policy initiatives. To facilitate and encourage construction of producer-owned/operated LNG terminals, FERC should adopt a policy that it will assert only its jurisdiction under NGA Section 3 (i.e. not under NGA Section 7) and will not impose an open access obligation. The reasons for this are as follows:

- LNG terminals built by LNG producers are a critical part of the integrated production process needed to treat and deliver gas into the U.S. pipeline grid. Producer-owned terminals are analogous to gas processing plants or other traditionally nonjurisdictional production-related facilities for which an open access requirement is considered unnecessary.

- International LNG development is extraordinarily complex with numerous partnership, host government, technical and commercial risks. Lack of assured terminal capacity for proprietary use will make it difficult for producers to justify the major investment needed for integrated LNG projects (i.e. wells, liquefaction, shipping and terminals), greatly reducing the likelihood that sufficient LNG terminals will be built in the U.S., and thus reducing the availability of LNG to meet U.S. energy needs.

- Proprietary utilization of LNG terminal capacity by LNG producers will not impede competition or consumer access to the supplies, as interested parties will have open access to the capacity of the pipelines into which the regasified LNG flows.

- Producer-owned LNG terminals will be constructed at the producer's risk, unlike pipeline-owned terminals where the cost is included in the pipeline company's rate base and captive pipeline customers become exposed to the risk of the investment.

- The assertion of Section 3 jurisdiction only, with no open access requirement, is within the scope of FERC's discretion and authority and consistent with its obligation to protect consumer interests.

With such a policy in place, international LNG producers would be able to invest with a high level of assurance that their supplies can access U.S. terminals and utilize terminal capacity with the operational flexibility that international LNG projects require. This policy will not preclude pipelines or gas traders from constructing "merchant" LNG terminals that may also attract LNG supplies available on the world market, nor preclude LNG producers from offering interruptible service to others using excess proprietary capacity in producer owned/operated LNG facilities.

Simplification and Expedition of Permitting

Before construction of a new LNG terminal in the U.S. can be commenced, FERC currently requires that certain authorizations be issued. This process has historically been very burdensome and time consuming. Under current permitting procedures, preparation of requests for authorization for a new LNG terminal and approval by the FERC would likely require 2 to 4 years for completion. With the critical need for new sources of energy to be brought on line quickly for U.S. consumers, it is imperative that the federal government reduce permitting delays by simplifying the application and approval process to the maximum extent possible consistent with appropriate safety and environmental concerns. The allocation of sufficient governmental agency resources for the review of permit applications will also be critical to expediting the overall permitting process. As FERC is not the only agency involved, the review and approval process at all other agencies involved should also be simplified and expedited. Expedited governmental approvals for LNG terminals are a prerequisite if LNG producers are to proceed quickly with the tremendous investments required for overall integrated LNG projects, and if LNG is to achieve its potential as an important and timely source of energy for U.S. consumers.

Attachment 3

Policy Modifications Necessary To Facilitate the Expeditious Development and Efficient Operation of Federally Regulated Natural Gas Pipeline Infrastructure

Summary of Proposed Policy

The flow of natural gas to meet America's growing energy needs would be facilitated through federal level natural gas pipeline related policies that:

1) Facilitate the expeditious construction of natural gas pipeline transportation and storage infrastructure,

2) Result in a more market-oriented and efficiency enhancing pipeline ratemaking process,

3) Prevent the exercise of monopoly market power, whereby promoting more competitive markets, and

4) Promote, unlike current policies, the development of new offshore natural gas supplies.

The adoption of such policies is necessary to meet, in a low cost and timely manner, the Nation's growing natural gas demand

In support of these objectives, the following modifications to existing Federal regulation, particularly to the policies and procedures of the Federal Energy Regulatory Commission (FERC) are needed:

1. **Expedited and coordinated environmental review by all involved Federal and State agencies is required to speed up the certification and construction of new natural gas pipeline facilities.**

   Currently, the environmental review process, including the review of landowner impacts, is the longest lead time variable in the approval process for new interstate pipeline facilities. As such, administration directives which require high priority, coordinated and non-duplicative agency actions with regard to environmental review will lead to a more expeditious, but never-the-less comprehensive, environmental assessment.

   Similarly, regarding the minimization of land-owner impacts, a proactive forward looking regional planning process among states should be encouraged, which seeks to identify intra-regional corridors for utility siting. This regional planning process should seek to minimize aggregate impacts by utilizing existing rights of way to the maximum practical extent, while seeking to reserve from development, land that may be necessary to facilitate the future growth of energy delivery systems.

Of particular importance is to prevent delays in infrastructure development associated with the construction of new facilities which pass through one state in order to provide expanded service in other states. This regional planning approach should be encouraged for the siting of both natural gas pipelines and electric transmission facilities.

The development of Alaskan gas and its possible transportation by pipeline to the L48 is being actively worked by us, and our partners. The scale and complexity of this project should it proceed will be greatly assisted by expeditious decision making at both the Federal and State levels

2. **The introduction of performance-based incentive mechanisms into the FERC's pipeline ratemaking methodology is necessary to increase the efficiency of natural gas markets.**

   The FERC's pipeline ratemaking methodologies should be modified to more effectively promote efficient natural gas markets. Although current practices encourage pipelines to become lower cost operators, they do little to facilitate the pass through to customers of pipeline efficiency gains. In competitive markets, service providers have to continuously pass efficiency gains on to customers, or lose their business.

   As such, the FERC's current ratemaking methodology should be modified to better align the economic interests of pipelines and shippers through the adoption of incentivized ratemaking, which rewards both pipelines (through the potential for achieving higher rates of return) and shippers (through lower rates).

   There is no need for the FERC to offer enhanced (above market) rates of return to pipelines in exchange for expedited capacity expansions. The record of proposed pipeline projects clearly indicates that extraordinary rates of return are not necessary to induce the timely expansion of pipeline infrastructure.

3. **To enhance competition in natural gas markets, the FERC should require that pipelines adopt a standardized capacity allocation procedure, which minimizes the opportunity for anti-competitive affiliate preferences and speculative capacity acquisitions made with the intent to manipulate natural gas prices.**

   The FERC should require natural gas pipelines to adopt capacity allocation procedures which eliminate the structural advantage that companies affiliated with the pipeline currently enjoy in obtaining capacity. Current FERC policies which favor affiliate transactions lead to market distortions, are anti-competitive in their effect, and exacerbate natural gas price volatility by facilitating the ability of the pipeline and its affiliates to manipulate the price of the gas commodity by constraining capacity availability.

Similarly, the FERC should be encouraged to minimize the opportunity for pipelines to enter into speculative profit sharing contracts with non-affiliates which eliminate the incentive for the pipeline to compete with the shipper. Such speculative contracts result in increased price volatility by reducing the level of competition.

4. **Modification of the FERC's new, and potentially disruptive policies, with regard to offshore pipelines and production related facilities is necessary to continue the long standing orderly and efficient development of new OCS natural gas supplies.**

The FERC should be encouraged to return to the highly effective OCS regulatory policies in effect prior to its recent (1999-2000) orders. These new policies, which have been opposed by producers, have the potential to undermine decades of orderly and expeditious development in the Gulf of Mexico.

In a recent order involving Sea Robin pipeline (1999), the FERC unreasonably decided to allow the partial deregulation of monopoly pipeline systems in the OCS. This order has the potential to result in unjustified and confiscatory price increases for captive shippers. In fact, the FERC issued the Sea Robin order without making any attempt to determine whether Sea Robin was operating in a competitive environment, or whether captive shippers had a meaningful choice of service providers. As a result the Sea Robin order has the potential to add great cost, uncertainty and delay to the development of offshore natural gas resources.

In Order No. 639 (2000), the FERC has inexplicitly and without any evidence of need, decided to depart from over 50 years of regulatory stability in the OCS, by extending its reach to previously unregulated offshore production related facilities, including non-pipeline facilities such as production and processing platforms. It is ironic that in a period when the FERC is attempting to exercise more light-handed regulation of pipelines, that it would impose regulations on offshore producers operations, without the showing of any public benefit to be gained by doing so.

April 30, 2001

Mr. Andrew Lundquist
Director
National Energy Policy Development Group
Vice President's Office
281 Old Executive Office Building
17th Street and Pennsylvania Avenue, NW
Washington, DC 20504

Dear Andrew:

When last we spoke, we discussed the need for technology related examples to facilitate the communication of the national energy policy recommendations. I am sending the following set of slides:

1. **Oil Field Imaging.** The state of seismic and reservoir imaging technology has significantly improved through the use of computer technology. Underground reservoir details are displayed quicker and with greater clarity. The comparison of conventional techniques with enhanced technology is illustrated in the first two figures.

2. **Drilling Technology.** Advances in drilling techniques have greatly improved productivity. Today's drilling methods allow the targeting of specific structures leading to fewer surprises, lower costs and greater overall hydrocarbon recovery. Two examples are illustrated in the slides 3 and 4.

3. **Field Development.** The merging of drilling technology with enhanced imaging leads to even greater production efficiency. I have included a slide showing a North Sea development example.

4. **Fuel Cells.** Fuel cell vehicles are at the cutting edge of technology. While these vehicles are not in production, current designs are based on existing vehicle platforms using current hybrid design characteristics. I have attached two slides to show the process and a proposed vehicle design.

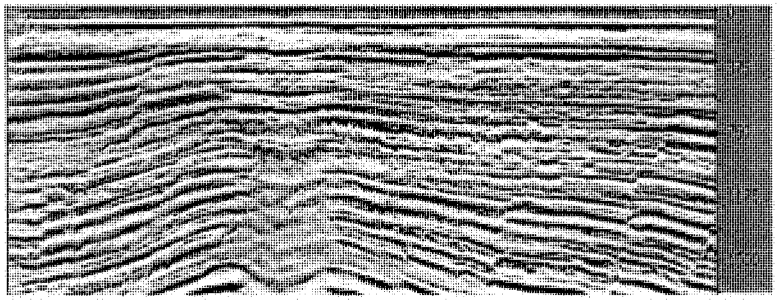
I hope these examples are helpful and I look forward to seeing you again soon.

Sincerely yours,

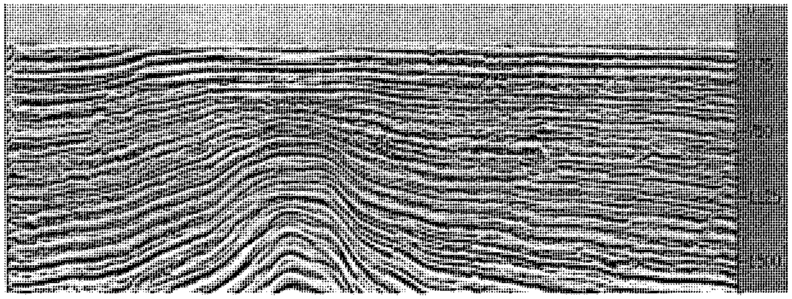
FH/JP
Attachments

Clearer Seismic Imaging

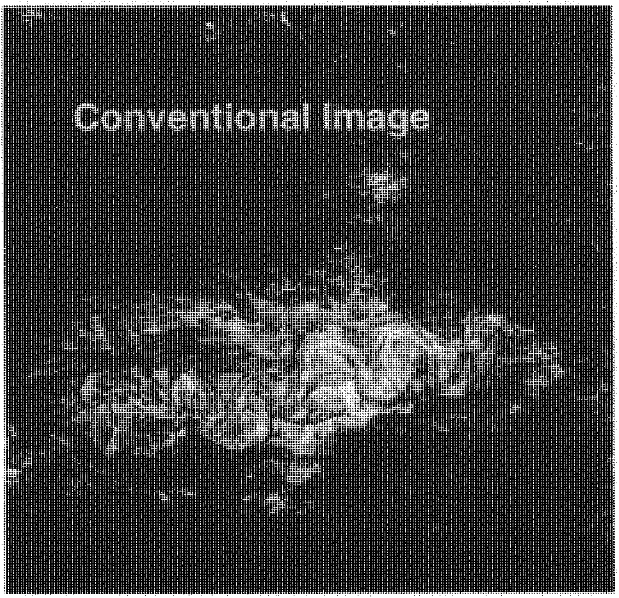
Targets obscured by shallow gas-charged sediments



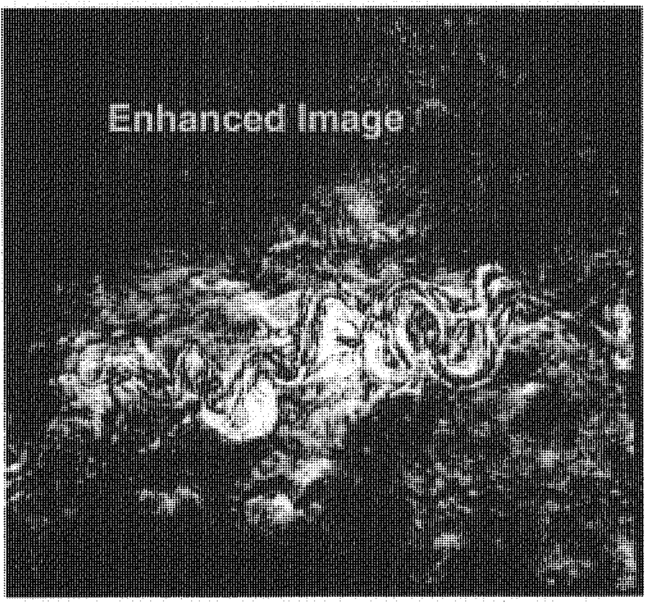
Improved Image using Advanced Depth Imaging Technology



Enhancing Reservoir Details

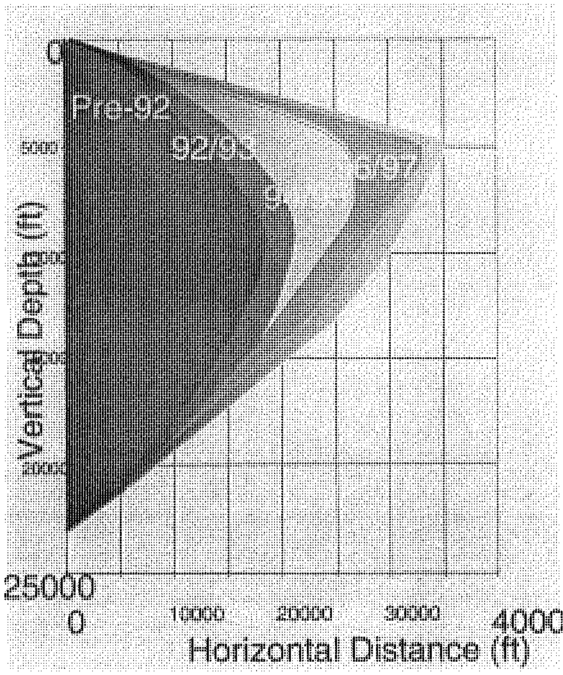


- Location of best/worst part
- Recognition of extent/shape

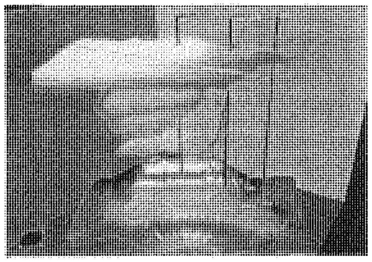


- Unravel stratigraphic complexities
- Uncover new opportunities

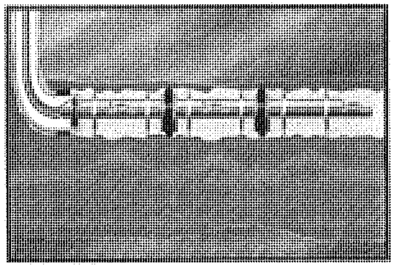
Advances in Drilling Technology



Actual Experience



Fewer Drilling Surprises

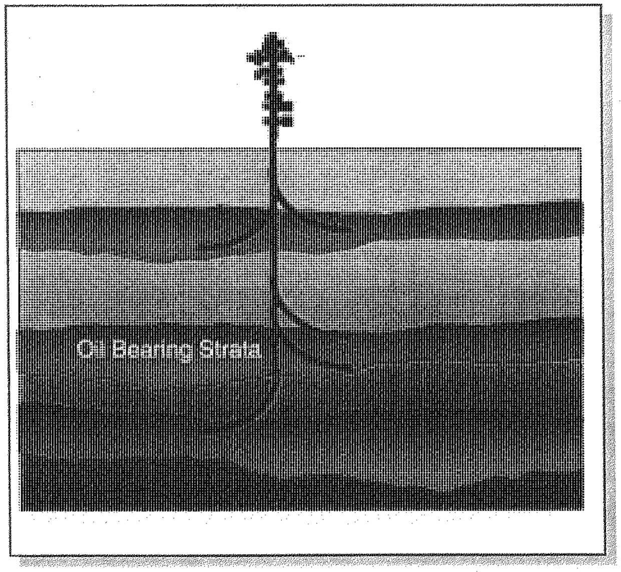


The Future: Intelligent Wells

Technological Advance Reducing Costs

(Multilateral Wells)

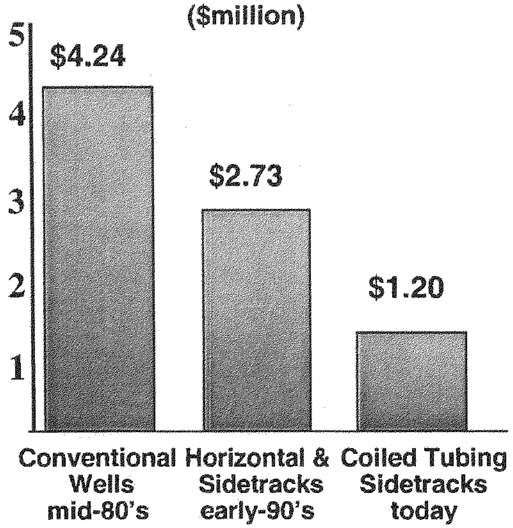
Prudhoe Bay



Average Well Cost

(ANS)

($million)

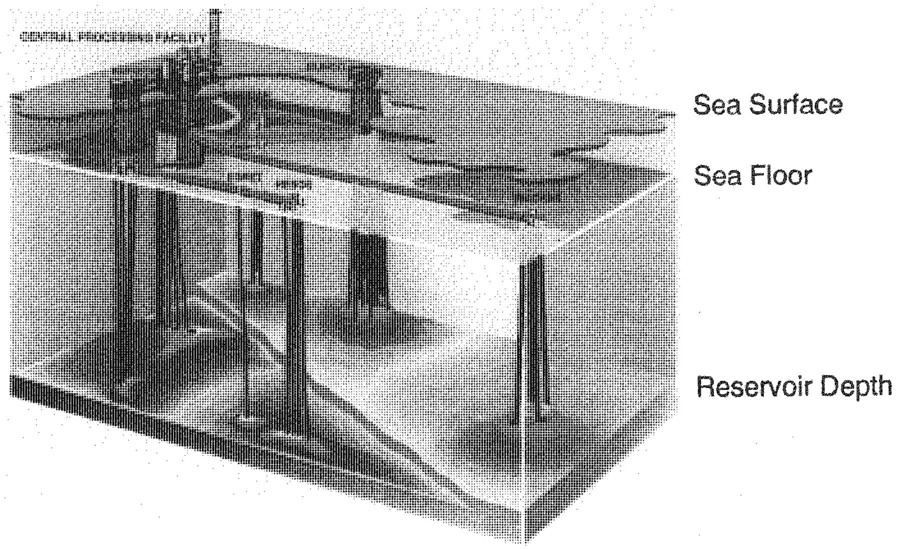


Source: BP

Technological Advance

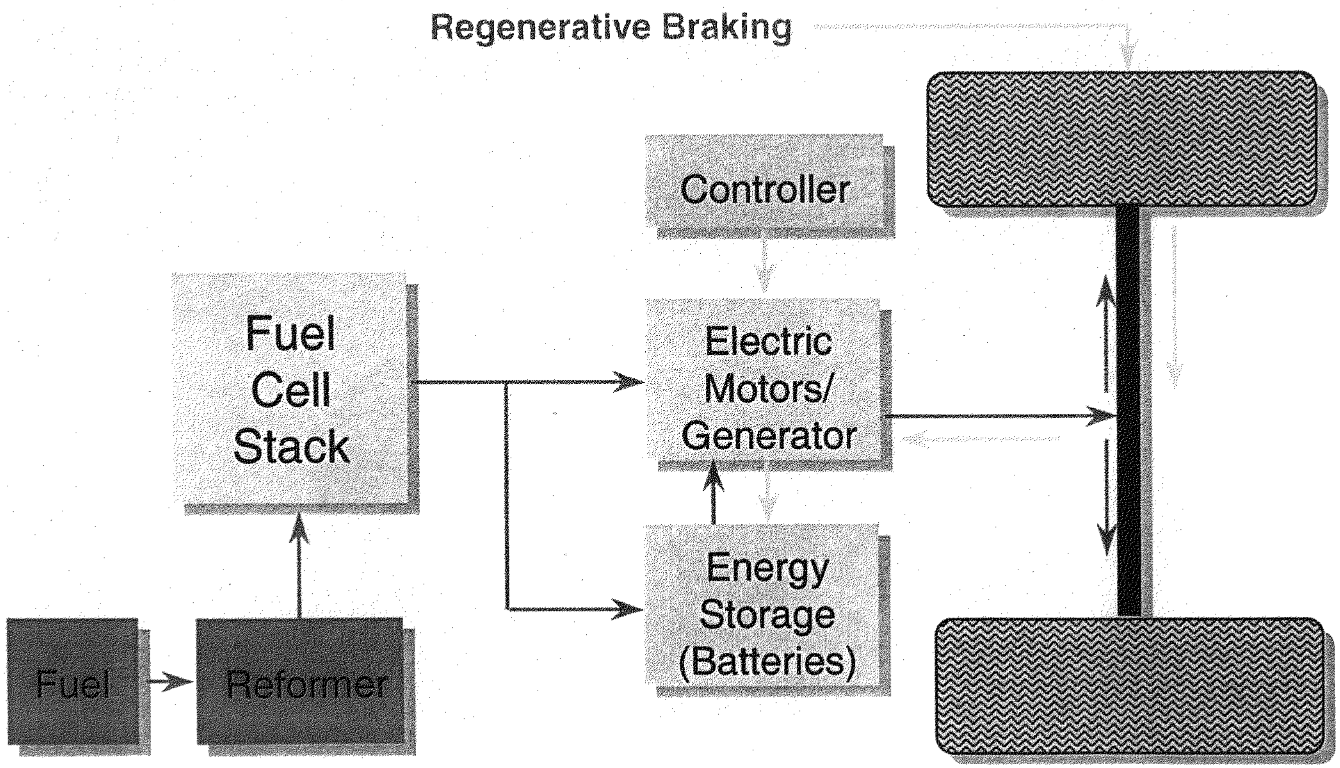
(UK North Sea example)

ETAPs - Small Field Development using Central Processing Facility



- ➢ A global phenomenon
- ➢ Increasing global supply of oil
- ➢ Reducing costs
- ➢ Increasing competition

Fuel Cell Vehicle



Regenerative Braking

Controller

Fuel
Cell
Stack

Electric
Motors/
Generator

Energy
Storage
(Batteries)

Fuel

Reformer

Chevron

Lisa B. Barry
Vice President and
General Manager

Policy, Government and
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June 7, 2006

Via Facsimile
202 225 3052

The Honorable Joe Barton
Chairman
Committee on Energy and Commerce
U.S. House of Representatives
2125 Rayburn House Office Building
Washington, DC 20515-4306

Via Facsimile
202 226 0371

The Honorable John D. Dingell
Ranking Member
Committee on Energy and Commerce
U.S. House of Representatives
2328 Rayburn House Office Building
Washington, DC 20515-2215

Dear Chairman Barton and Ranking Member Dingell:

In two recent Energy and Commerce Committee hearings, and in a recent letter addressed to Chairman Barton, various Members of the Committee have referred to and commented on what has been described as a "Chevron document" dated November 30, 1995. The document has been used to create the inaccurate impression that the oil industry in general, and Chevron in particular, have pursued a strategy of closing refineries and reducing refining capacity in order to increase profits. Because the document at issue has never been quoted in full and in context, and because it certainly does not reflect either Chevron's policy or activities, I am writing in an effort to make clear both the document's origins and Chevron's own expansions of refining capacity in the United States during the last decade.

While only a fragment of the document has been quoted by Members in the recent letter and hearings, the paragraph of which that fragment is a part makes clear that the employee who wrote it was neither offering his own advice nor describing Chevron's business plans. The full paragraph reads:

> "**Refining/Marketing/S&D:** A senior energy analyst at the recent API convention warned that if the U.S. petroleum industry doesn't reduce its refining capacity, it will never see any substantial increase in refining margins, pointing out the recent volatility in refining margins over the past 12 months. U.S. average refining margins were sitting at the break-even point of $3/bbl in March, surged to $6/bbl in May, then dropped to 50cts/bbl in September before crawling up to the present margin of $2/bbl. In the last nine months, gasoline demand has been healthy and inventories have remained close to record lows, factors that should normally lead to higher prices. However, refining utilization has been rising, sustaining high levels of operations, thereby keeping prices low. ***Implication: in what alternate modes can the refinery operate given low-margin economics?***"

The "senior energy analyst" being paraphrased here was not an employee of API, Chevron or any other oil company. His remarks were heard not only by industry representatives but by all other attendees at his speech, including the trade press, which later reported on the speech.

The remarks, offered near the end of 1995, make apparent that for several months of that year, the U.S. refining industry on average lost money on every barrel of oil it refined. In fact, Chevron's 1995 U.S. downstream earnings were down by 77% compared to 1994. By comparison, our U.S. downstream capital expenditures in 1995 were nearly 12 times what we made that year in that segment of our business, and nearly three times what we had made in the preceding year. Indeed, during 1994 and 1995, we spent approximately $1 billion on new facilities at our two California refineries, in El Segundo and Richmond, to make a unique blend of cleaner-burning gasoline mandated by the California Air Resources Board (CARB).

More to the point, in the ten years since that memo was written, and contrary to the analyst's remarks in November 1995, Chevron has not closed a single refinery. We operated six U.S. refineries at that time – in El Segundo and Richmond, California; Pascagoula, Mississippi; Salt Lake City, Utah; Honolulu, Hawaii and El Paso Texas. We still operate the first five refineries, and sold our interest in the sixth (El Paso) to a third party which is still operating it. In addition to the CARB gasoline investments mentioned above, we have also invested substantial sums to expand gasoline production capacity. Most recently, in 2005, we completed a modification at El Segundo to increase its ability to produce more gasoline and other light products. We have also begun a similar modification at our Pascagoula, Mississippi refinery, to increase its ability to produce gasoline – a project we hope to complete by the end of 2006.

During the Committee's September 7, 2005 hearing entitled "Hurricane Katrina's Effect on Gasoline Supply and Prices," in an exchange with a witness from the Department of Energy, Rep. Markey stated:

> "Chevron said that in its document in 1995, they said, we will never see any substantial increase in refining margins if we don't reduce—*if we don't reduce, that is, Chevron doesn't reduce its refining capacity.*" (Emphasis added.)

Rep. Stupak made a similar reference to the 1995 document in the Committee's hearing on May 10, 2006. Even more recently, in a letter addressed to you, several Members characterized the document as follows:

> "In this Chevron document, *the author described* how the refining industry would not be able to increase its profits unless it reduced its refining capacity." (Emphasis added.)

Contrary to the inference about Chevron's business plans or conduct that Members and other listeners might draw from the inaccurate characterizations of this document recently bandied about, Chevron pointedly did not take the course advocated in the analyst's remarks ten years ago. We respectfully believe that in the interest of honest and fair debate of these important and complex issues, our company should not be incorrectly labeled as either an author, advocate, or participant in that suggested market strategy.

In 2001, the California Supreme Court had the opportunity to consider some of these very issues in connection with a class-action lawsuit that had been brought against Chevron and several other California refiners and marketers in 1996. The plaintiffs alleged violations of California's state antitrust and unfair competition statutes, claiming that the companies had entered into an unlawful conspiracy to restrict the output of CARB gasoline and thus to raise its price. The California Supreme Court, in a unanimous 7-0 decisions authored by the late Justice Stanley Mosk, affirmed summary judgment in favor of Chevron and the other defendants. *Aguilar v. Atlantic Richfield Co.*, 25 Cal.4th 826, 24 P.3d 493 (2001). Contrary to any insinuation that Chevron might have followed the energy analyst's opinion following the November 1995 API convention, the California Supreme Court noted:

> "It is impossible to summarize the petroleum companies' evidence within a scope that would be appropriate to this opinion. The Court of Appeal's recounting itself fills 38 pages. With that said, the petroleum companies' evidence showed independence rather than collusion as to their most fundamental strategies with respect to CARB gasoline. *For example, at one end of the range, there was Chevron's altogether active plan, which was to 'gain an advantage over its competitors by becoming the largest producer of CARB gasoline in the world.'* At the other end, there was Union Oil's relatively passive stance, which would put it at a disadvantage vis-à-vis its competitors in this regard, and would lead it to exit the market completely." 24 P.3d at 518 (emphasis added).

In addition to the lower court's finding that "the 'actions' of the petroleum companies 'were a pro-competitive response to a regulatory requirement,'" *id.* at 503 It should be obvious that the only way in which Chevron could execute the business strategy described above was to maintain and ultimately to expand its capacity to produce gasoline in California – something we in fact did, and at great expense. Chevron fully recognizes that energy will be one of the defining issues of this century. Now more than ever, we need to work together to determine how we will meet the energy needs of the entire world in this century and beyond. Whatever actions we take, we must look not just to next year, but to the next 50 years. Innovation, collaboration and conservation are the cornerstones on which our energy future must be built, and we want to work with you and all Members of Congress to help be part of the solution. We hope that by bringing greater clarity to recent discussions of our company's U.S. downstream efforts over the past decade, we will help to advance that dialogue. We remain ready to work in good faith with you and all Members of the Committee to achieve those goals.

Thank you for your consideration.

Sincerely,

Lisa B. Barry

cc: Members of House Energy & Commerce Committee

NATIONAL PETROLEUM COUNCIL

July 2007

HARDTRUTHS

Facing the Hard Truths about Energy

Instructions for navigating this electronic version of the report

This National Petroleum Council report contains various hyperlinks to pages within the report as well as Topic Papers and websites. Text in brick red and headlines followed by "✦" indicate hyperlinks. To return to the page in this report prior to a hyperlink, please use the following commands:

PC users
Right-click on mouse and select "Previous View"

MAC users
Hold control key and click mouse, select "Previous View"

This action can be repeated to return to an earlier page if you have moved several pages since clicking on the hyperlink.

If clicking on the hyperlink takes you to a Topic Paper or website, simply close the linked window to return to this NPC report.

Links to websites were active at the time of publication.

HARDTRUTHS

Facing the Hard Truths about Energy

A comprehensive
view to 2030 of
global oil and
natural gas

2007

■

NATIONAL
PETROLEUM COUNCIL

NATIONAL PETROLEUM COUNCIL
An Oil and Natural Gas Advisory Committee to the Secretary of Energy

1625 K Street, N.W.
Washington, D.C. 20006-1656

Phone: (202) 393-6100
Fax: (202) 331-8539

July 18, 2007

The Honorable Samuel W. Bodman
Secretary of Energy
Washington, D.C. 20585

Dear Mr. Secretary:

In response to the questions posed in your letter of October 5, 2005, the National Petroleum Council conducted a comprehensive study considering the future of oil and natural gas to 2030 in the context of the global energy system. The complexity of today's integrated energy markets and the urgency surrounding today's energy issues demanded a study that included:

- An integrated view of supply, demand, infrastructure, technology, and geopolitics
- A comprehensive review of public and aggregated proprietary energy outlooks
- In-depth analysis of technology trends and opportunities
- Policy options viewed through economic, security, and environmental lenses
- More than 350 participants from diverse backgrounds and organizations
- Dialogue with more than 1,000 persons and groups actively involved in energy.

The Council found that total global demand for energy is projected to grow by 50-60 percent by 2030, driven by increasing population and the pursuit of improving living standards. At the same time, there are accumulating risks to the supply of reliable, affordable energy to meet this growth, including political hurdles, infrastructure requirements, and availability of a trained work force. We will need all economic, environmentally responsible energy sources to assure adequate, reliable supply.

There is no single, easy solution to the global challenges ahead. Given the massive scale of the global energy system and the long lead-times necessary to make material changes, actions must be initiated now and sustained over the long term.

Over the next 25 years, the United States and the world face hard truths about the global energy future:

- Coal, oil, and natural gas will remain indispensable to meeting total projected energy demand growth.
- The world is not running out of energy resources, but there are accumulating risks to continuing expansion of oil and natural gas production from the conventional sources relied upon historically. These risks create significant challenges to meeting projected total energy demand.
- To mitigate these risks, expansion of all economic energy sources will be required, including coal, nuclear, biomass, other renewables, and unconventional oil and natural gas. Each of these sources faces significant challenges including safety, environmental, political, or economic hurdles, and imposes infrastructure requirements for development and delivery.
- "Energy Independence" should not he confused with strengthening energy security. The concept of energy independence is not realistic in the foreseeable future, whereas U.S. energy security can be enhanced by moderating demand, expanding and diversifying domestic energy supplies, and strengthening global energy trade and investment. There can be no U.S. energy security without global energy security.

The Hon. Samuel W. Bodman
July 18, 2007
Page Two

- A majority of the U.S. energy sector workforce, including skilled scientists and engineers, is eligible to retire within the next decade. The workforce must be replenished and trained.
- Policies aimed at curbing carbon dioxide emissions will alter the energy mix, increase energy-related costs, and require reductions in demand growth.

The Council proposes five core strategies to assist markets in meeting the energy challenges to 2030 and beyond. All five strategies are essential—there is no single, easy solution to the multiple challenges we face. However, we are confident that the prompt adoption of these strategies, along with a sustained commitment to implementation, will promote U.S. competitiveness by balancing economic, security, and environmental goals.

The United States must:

- Moderate the growing demand for energy by increasing efficiency of transportation, residential, commercial, and industrial uses.
- Expand and diversify production from clean coal, nuclear, biomass, other renewables, and unconventional oil and gas; moderate the decline of conventional domestic oil and gas production; and increase access for development of new resources.
- Integrate energy policy into trade, economic, environmental, security, and foreign policies; strengthen global energy trade and investment; and broaden dialog with both producing and consuming nations to improve global energy security.
- Enhance science and engineering capabilities and create long-term opportunities for research and development in all phases of the energy supply and demand system.
- Develop the legal and regulatory framework to enable carbon capture and sequestration. In addition, as policymakers consider options to reduce carbon dioxide emissions, provide an effective global framework for carbon management, including establishment of a transparent, predictable, economy-wide cost for carbon dioxide emissions.

The attached report, *Facing the Hard Truths about Energy*, details findings and recommendations based on comprehensive analyses developed by the study teams.

The Council looks forward to sharing this study and its results with you, your colleagues, and broader government and public audiences.

Respectfully submitted,

Lee R. Raymond
Chair

Andrew Gould
Vice Chair, Technology

John J. Hamre
Vice Chair, Geopolitics
& Policy

David J. O'Reilly
Vice Chair, Supply

Daniel H. Yergin
Vice Chair, Demand

Attachment

HARDTRUTHS

Facing the Hard Truths about Energy

A comprehensive
view to 2030 of
global oil and
natural gas

A report of the National Petroleum Council
July 2007

Committee on Global Oil and Gas
Lee R. Raymond, Chair

NATIONAL PETROLEUM COUNCIL

Lee R. Raymond, *Chair*
Claiborne P. Deming, *Vice Chair*
Marshall W. Nichols, *Executive Director*

U.S. DEPARTMENT OF ENERGY

Samuel W. Bodman, *Secretary*

The National Petroleum Council is a federal advisory committee to the Secretary of Energy.

The sole purpose of the National Petroleum Council is to advise, inform, and make recommendations to the Secretary of Energy on any matter requested by the Secretary relating to oil and natural gas or to the oil and gas industries.

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**A detailed glossary of terms used in this report is available at www.npc.org and on the CD that accompanies the printed report.*

PREFACE

NATIONAL PETROLEUM COUNCIL

The National Petroleum Council (NPC) is an organization whose sole purpose is to provide advice to the federal government. At President Harry Truman's request, this federally chartered and privately funded advisory group was established by the Secretary of the Interior in 1946 to represent the oil and gas industries' views to the federal government: advising, informing, and recommending policy options. During World War II, under President Franklin Roosevelt, the federal government and the Petroleum Industry War Council had worked closely together to mobilize the oil supplies that fueled the Allied victory. President Truman's goal was to continue that successful cooperation in the uncertain postwar years. Today, the NPC is chartered by the Secretary of Energy under the Federal Advisory Committee Act of 1972.

About 175 in number, Council members are selected by the Energy Secretary to assure well-balanced representation from all segments of the oil and gas industries, all sections of the country, and from large and small companies. Members are also selected from outside the oil and gas industries, representing academic, financial, research, Native-American, and public-interest organizations and institutions. The Council provides a forum for informed dialogue on issues involving energy, security, the economy, and the environment in an ever-changing world.

STUDY REQUEST

By letter dated October 5, 2005, Secretary of Energy Samuel W. Bodman requested that the National Petroleum Council undertake a study on the ability of global oil and natural gas supply to keep pace with growing world demand. Specifically, the Secretary stated that key questions to be addressed in the study may include:

- What does the future hold for global oil and natural gas supply?
- Can incremental oil and natural gas supply be brought on-line, on-time, and at a reasonable price to meet future demand without jeopardizing economic growth?
- What oil and gas supply strategies and/or demand-side strategies does the Council recommend the U.S. pursue to ensure greater economic stability and prosperity?

(Appendix A contains a copy of the Secretary's request letter and a description of the NPC.)

STUDY ORGANIZATION

Responding to the Secretary's request, the Council established a Committee on Global Oil and Gas to study this topic and to supervise preparation of a draft report for the Council's consideration. The Council also established a Coordinating Subcommittee and four Task Groups—on Demand, Supply, Technology, and Geopolitics & Policy—to assist the Committee in conducting the study. These study groups were supported by three dozen Subgroups focused on specific subject areas. The box on the next page lists those who served as leaders of the study.

The members of the various study groups were drawn from NPC members' organizations as well as from many other U.S. and international industries, U.S. and international governments, non-governmental organizations, financial institutions,

Global Oil and Natural Gas Study Leaders

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Lee R. Raymond
Retired Chairman and
Chief Executive Officer
Exxon Mobil Corporation

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Deputy Secretary of Energy
U.S. Department of Energy

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John J. Hamre
President and Chief Executive Officer
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Chair – Supply Task Group
Donald L. Paul
Vice President and Chief Technology Officer
Chevron Corporation

Chair – Technology Task Group
Rodney F. Nelson
Vice President
Innovation and Collaboration
Schlumberger Limited

Chair – Geopolitics & Policy Task Group
Frank A. Verrastro
Director and Senior Fellow
Center for Strategic & International Studies

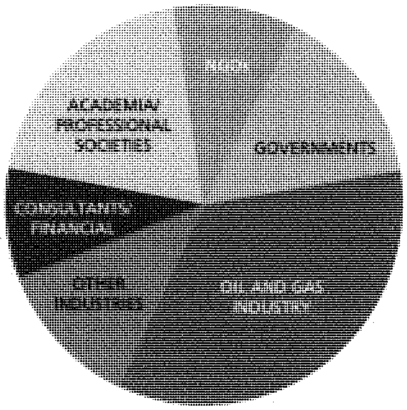
consultancies, academia, and research groups. More than 350 people served on the study's Committee, Subcommittee, Task Groups, and Subgroups. (Appendix B contains rosters of these study groups.)

In addition to these study group participants, many more people were involved through outreach activities. These efforts were an integral part of the study with the goal of informing and soliciting input from a broad range of interested parties. More than two dozen sessions were held with staff of U.S. executive branch agencies, U.S. congressional committees, and state and local governments; non-governmental organizations; academia; professional societies; and industries. The outreach process also included key consuming and producing countries. Secretary Bodman contacted 19 energy ministries around the world to encourage supply and demand data from governments and national energy companies. Many countries provided constructive responses.

The data and feedback provided by the global energy community and other interested parties involved in the outreach sessions were documented and used to develop the insights for the future of the energy sector and to ensure that the study was addressing the critical issues associated with energy. This stakeholder input represented a wide range of views/opinions. This information was an integral part of the data sets analyzed and considered to develop the key findings and recommendations. (Appendix C provides a description of the study's outreach process and sessions.)

Figure P-1 illustrates the diversity of participation in the study process.

Study group and outreach participants contributed in a variety of ways, ranging from full-time work in multiple study areas, to involvement on a specific topic, to reviewing proposed materials, or to participating solely in an outreach session. Involvement in these activities should not be construed as endorsement or agreement with all the statements, findings, and recommendations in this report. Additionally, while U.S. government participants provided significant assistance in the identification and compilation of data and other information, they did not take positions on the study's policy recommendations. As a federally appointed and chartered advisory committee, the National Petroleum Council is solely responsible for the final advice provided to the Secretary of Energy. However, the Council believes that the broad and diverse study group and outreach participation has informed and enhanced its study and advice. The Council is very appreciative of the commitment and contributions from all who participated in the process.



65% PARTICIPANTS FROM OUTSIDE
OF OIL AND GAS INDUSTRY

350+ PARTICIPANTS, PLUS INPUT
FROM 1,000+ OTHERS

FIGURE P-1. Broad Participation

STUDY SCOPE AND APPROACH

The study's primary focus was on oil and natural gas. However, all energy forms were assessed as they are elements of an interrelated and competitive global energy market. In fact, an understanding of all energy forms was necessary in order to provide meaningful advice on oil and natural gas. The study was conducted with a set of guiding principles that the study would:

- Not create another "grassroots" energy forecast of demand, supply, or prices, but rather focus on analysis of existing projections to identify underlying assumptions, understand why they differ, and thereby identify important factors governing the future of oil and gas
- Gather and analyze public data (from government, academia, and others) and aggregated proprietary data (from international oil companies and consultants)
- Solicit input from a broad range of interested parties including non-governmental organizations and foreign countries
- Emphasize long-term conditions to 2030 and beyond, not near-term energy market volatility
- Make recommendations supported by data and science, and develop policy options and recommendations only after completing the study analyses, interpretation, and findings phase to guard against predetermined conclusions
- Frame detailed questions to ensure all study teams work within their scope and on time
- Comply fully with antitrust laws and regulations, and the Federal Advisory Committee Act. While the Council recognizes the important role price plays in both demand and supply actions, antitrust sensitivities precluded the study from addressing such impacts or accessing future price levels.

A large, broad, and diverse group of other studies and projections served as the underpinning of the NPC analyses. The NPC attempted to examine and use the full range of available projections:

- Data were provided by the International Energy Agency (IEA) and U.S. Energy Information Administration (EIA)—the two most widely used and respected sources of energy projections.

- A broad survey of proprietary energy projections was also conducted. As an integral part of this process, the NPC engaged the public accounting firm Argy, Wiltse & Robinson, P.C. to receive, aggregate, and protect proprietary data responses.
- A Wide-Net process collected additional publicly available projections from academia, governmental organizations, non-governmental groups, and other interests.
- A Data Warehouse was developed to store and assist in analysis of all collected projections. The warehouse data are included on the CD accompanying printed copies of this report.
- A Parallel Studies process examined numerous other recent reports regarding aspects of energy policy to inform the work of the NPC study's Coordinating Subcommittee. (Appendix D provides summaries of the studies.)

The Demand and Supply Task Groups focused primarily on the analysis and interpretation of the range of projections for world energy demand and supply to 2030 and the key assumptions/drivers underlying those projections. The Technology Task Group examined the range of technology assumptions in the projections surveyed and how these technologies might affect world energy supply/demand over the next 25 years. The Geopolitics & Policy Task Group had two focus areas. Its geopolitical analyses assessed how sovereign national, regional, and global policy decisions might affect global supply and demand outlooks. Its policy work involved the integration of options from the various study groups into a concise set of recommendations for the Secretary of Energy reflecting the tradeoffs among the economy, security, and the environment. In addition to the work of the Task Groups, the study addressed several overarching themes: energy efficiency, carbon management, and macroeconomic issues.

The output from these multiple efforts underpin the NPC's recommended supply- and demand-side strategies, and form the basis for its policy recommendations to the Secretary of Energy.

(See the Report Chapters and Topic Papers for more detailed descriptions of the scopes of work, framing questions, and approaches used by the various study groups.)

STUDY REPORT

In the interest of transparency and to help readers better understand this study, the NPC is making the study results and many of the documents developed by the study groups available to all interested parties as follows:

- *Executive Summary* provides insights on energy market dynamics as well as advice on an integrated set of actions needed immediately to ensure adequate and reliable supplies of energy, while assuring continued expansion of prosperity including economic growth, global security, and environmental responsibility.
- *Report Chapters* contain summary results of the analyses conducted by the Demand, Supply, Technology, and Geopolitics & Policy Task Groups; a discussion on Carbon Management; a full listing of the study's recommendations; and a description of the study's methodology. These chapters provide supporting data and analyses for the findings and recommendations presented in the *Executive Summary*.
- *Appendices* contain Council and study group rosters, a description of the study's outreach process, and other information.
- *Topic Papers*, which can be found on the CD inside the back cover of this report, include detailed, specific subject matter papers and reports prepared by the Task Groups and their Subgroups. These Topic Papers formed the basis for the analyses that led to development of the summary results presented in the report's Executive Summary and Chapters. The Council believes that these materials will be of interest to the readers of the report and will help them better understand the results. The members of the National Petroleum Council were not asked to endorse or approve all of the statements and conclusions contained in these documents but, rather, to approve the publication of these materials as part of the study process. (See the description of the CD in Appendix E for abstracts on topic papers and a list of other documents included.)

(Published copies of the report and the CD can be purchased from the NPC or viewed and downloaded from its website: www.npc.org)

■

EXECUTIVE SUMMARY

The American people are very concerned about energy—its availability, reliability, cost, and environmental impact. Energy also has become a subject of urgent policy discussions. But energy is a complex subject, touching every part of daily life and the overall economy, involving a wide variety of technologies, and deeply affecting many aspects of our foreign relations. The United States is the largest participant in the global energy system—the largest consumer, the second largest producer of coal and natural gas, and the largest importer and third largest producer of oil. Developing a framework for considering America's oil and natural gas position now and for the future requires a broad view and a long-term perspective; both are provided in this study.

During the last quarter-century, world energy demand has increased about 60 percent, supported by a global infrastructure that has expanded to a massive scale. Most forecasts for the next quarter-century project a similar percentage increase in energy demand from a much larger base. Oil and natural gas have played a significant role in supporting economic activity in the past, and will likely continue to do so in combination with other energy types. Over the coming decades, the world will need better energy efficiency and all economic, environmentally responsible energy sources available to support and sustain future growth.

Fortunately, the world is not running out of energy resources. But many complex challenges could keep these diverse energy resources from becoming the sufficient, reliable, and economic energy supplies upon which people depend. These challenges are compounded by emerging uncertainties: geopolitical influences on energy development, trade, and security; and increasing constraints on carbon dioxide (CO_2) emissions that could impose changes in future energy use. While risks have always typified the energy business, they are now accumulating and converging in new ways.

The National Petroleum Council (NPC) examined a broad range of global energy supply, demand, and technology projections through 2030. The Council identified risks and challenges to a reliable and secure energy future, and developed strategies and recommendations aimed at balancing future economic, security, and environmental goals.

The United States and the world face hard truths about the global energy future over the next 25 years:

- Coal, oil, and natural gas will remain indispensable to meeting total projected energy demand growth.
- The world is not running out of energy resources, but there are accumulating risks to continuing expansion of oil and natural gas production from the conventional sources relied upon historically. These risks create significant challenges to meeting projected energy demand.
- To mitigate these risks, expansion of all economic energy sources will be required, including coal, nuclear, renewables, and unconventional oil and natural gas. Each of these sources faces significant challenges—including safety, environmental, political, or economic hurdles—and imposes infrastructure requirements for development and delivery.
- "Energy Independence" should not be confused with strengthening energy security. The concept of energy independence is not realistic in the foreseeable future, whereas U.S. energy security can

be enhanced by moderating demand, expanding and diversifying domestic energy supplies, and strengthening global energy trade and investment. There can be no U.S. energy security without global energy security.

- A majority of the U.S. energy sector workforce, including skilled scientists and engineers, is eligible to retire within the next decade. The workforce must be replenished and trained.
- Policies aimed at curbing CO_2 emissions will alter the energy mix, increase energy-related costs, and require reductions in demand growth.

Free and open markets should be relied upon wherever possible to produce efficient solutions. Where markets need to be bolstered, policies should be implemented with care and consideration of possible unintended consequences. The Council proposes five core strategies to assist markets in meeting the energy challenges to 2030 and beyond. All five strategies are essential—there is no single, easy solution to the multiple challenges we face. However, the Council is confident that the prompt adoption of these strategies, along with a sustained commitment to implementation, will promote U.S. competitiveness by balancing economic, security, and environmental goals. The United States must:

- Moderate the growing demand for energy by increasing efficiency of transportation, residential, commercial, and industrial uses.
- Expand and diversify production from clean coal, nuclear, biomass, other renewables, and unconventional oil and natural gas; moderate the decline of conventional domestic oil and natural gas production; and increase access for development of new resources.
- Integrate energy policy into trade, economic, environmental, security, and foreign policies; strengthen global energy trade and investment; and broaden dialogue with both producing and consuming nations to improve global energy security.
- Enhance science and engineering capabilities and create long-term opportunities for research and development in all phases of the energy supply and demand system.
- Develop the legal and regulatory framework to enable carbon capture and sequestration (CCS). In addition, as policymakers consider options to reduce CO_2 emissions, provide an effective global framework for carbon management, including establishment of a transparent, predictable, economy-wide cost for CO_2 emissions.

The Council identified these strategies by drawing upon more than 350 expert participants with wide-ranging backgrounds to provide analysis, information, and insight. Additionally, extensive outreach efforts involved more than 1,000 people actively engaged in energy. Task Groups for this study reviewed a broad range of public and aggregated proprietary studies in order to understand and evaluate the many assumptions and forces behind recent global energy projections.

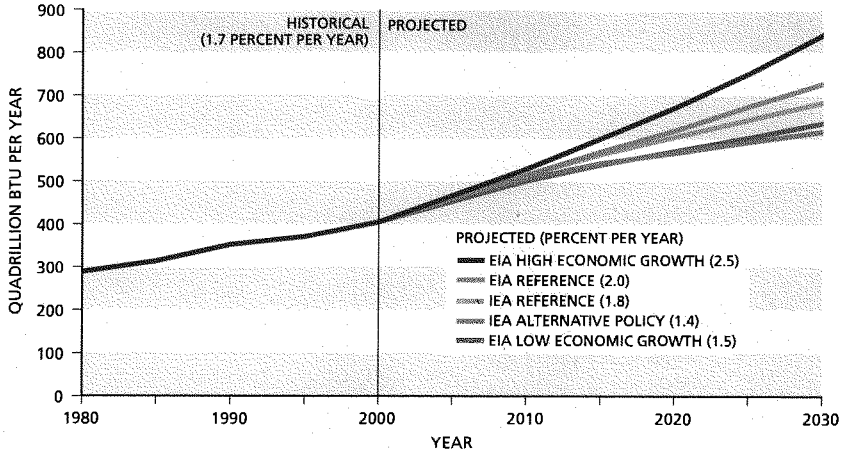
Given the massive scale of the global energy system and the long lead times necessary to make significant changes, concerted actions must be taken now, and sustained over the long term, to promote U.S. competitiveness by balancing economic, security, and environmental goals. The Council's findings and recommendations are summarized below and explained in detail in the report chapters.

THE GROWING DEMAND FOR ENERGY

Over the coming decades, energy demand will grow to increasingly higher levels as economies and populations expand. This will pressure the supply system and require increased emphasis on energy-use efficiency.

Energy is essential to the economic activity that sustains and improves the quality of life. Projections for future energy needs generally assume expanding economies and populations, which drive continued energy demand growth. Over time, the efficiency of energy use has improved, thanks to the combined effects of technological advancement, education of consumers, and policy initiatives. These developments have allowed growth in economic activity to outpace growth in energy use. Differing assumptions for the world's population, economic activity, and energy efficiency result in varying projections for future energy demand, as shown in Figure ES-1.

Historically, energy consumption has been concentrated in the developed world, where economic activity has been centered. Today, the developed world, represented by the Organisation for Economic Co-operation and Development (OECD),[1] uses half of the world's total energy to produce half of the world's



Note: A quadrillion Btu is one million billion British thermal units. One quadrillion Btu per year is the energy equivalent of about 500,000 barrels per day of oil.
Sources: EIA: U.S. Energy Information Administration, *International Energy Outlook 2006.*
IEA: International Energy Agency, *World Energy Outlook 2006.*

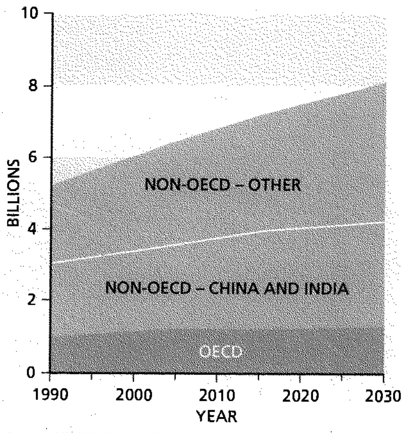
FIGURE ES-1. *World Energy Demand—Average Annual Growth Rates*

Gross Domestic Product.[2] However, over 80 percent of the world's population is projected to live in developing countries by 2030, as shown in Figure ES-2.

Many developing countries are just reaching the point where individual wealth and energy consumption start to accelerate. For example, while the number of cars in China more than doubled between 2000 and 2006, there remains just one car for every 40 people[3] whereas the United States has one car for every two people.[4] Thus, dramatic further growth in vehicle sales and demand for fuel in China are very likely. As this accelerating consumption combines with large and growing populations, it becomes likely that most new energy demand growth will occur in the developing world, with one projection shown in Figure ES-3.

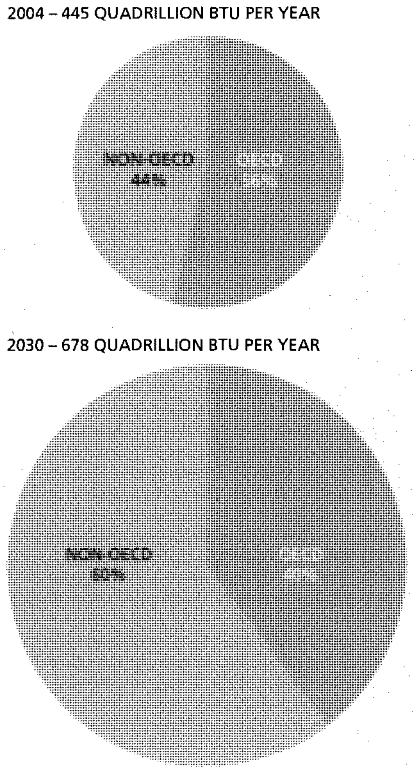
THE ENERGY SUPPLY LANDSCAPE

The world uses a wide variety of energy sources today. Oil and natural gas now provide nearly 60 percent of



Source: *UN World Population Prospects.*

FIGURE ES-2. *World Population*

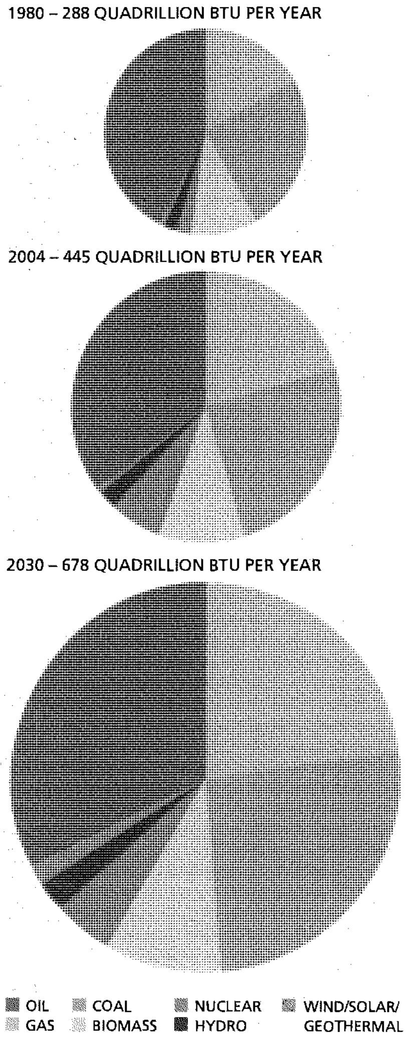


Source: IEA, *World Energy Outlook 2006.*

FIGURE ES-3. *World Energy Demand Growth from 2004 to 2030*

world primary energy,[5] as shown in Figure ES-4, and it is a hard truth that oil and natural gas will remain indispensable to meeting the projected growth in energy demand.

It is another hard truth that a rapidly growing world economy will require large increases in energy supplies over the next quarter-century. Expansion of all economic energy sources will be required to meet demand reliably, including coal, nuclear, renewables,



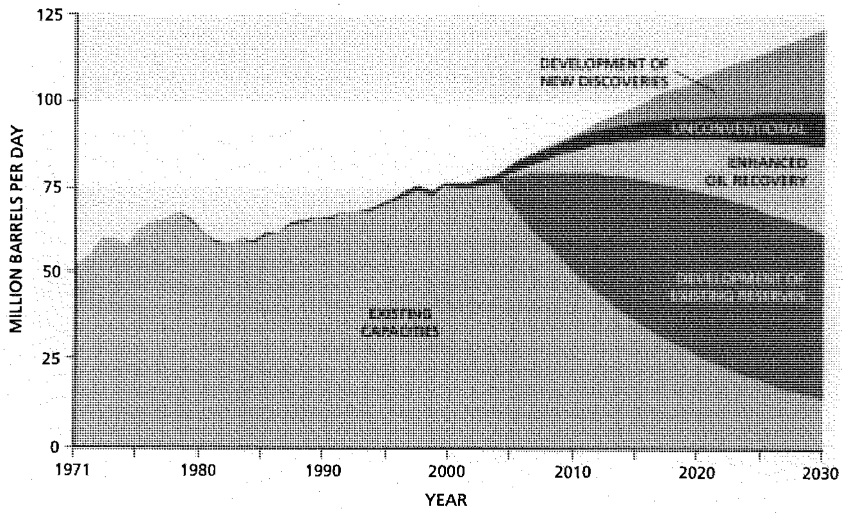
Source: IEA, *World Energy Outlook 2006.*

FIGURE ES-4. *World Energy Supply – Historical and Projected* and unconventional oil and natural gas. All energy sources have their own challenges that must be overcome to be produced, delivered, and used on an ever-increasing scale.

Current assessments for both oil and natural gas indicate large in-place volumes of resource. The natural gas resource appears more than adequate to meet the increased natural gas production typically anticipated by energy outlooks over the study period.

Future oil supply will come from a variety of sources, including existing production capacities, development of existing reserves, application of enhanced oil recovery, expansion of unconventional liquids, and development of new discoveries. Figure ES-5 is an illustrative example of these sources as depicted by the IEA in its *World Energy Outlook 2004*. There is uncertainty about the potential of the oil resource base to sustain growing oil production rates. Additional uncertainty surrounds the industry's potential to overcome multiple increasing risks, including access to promising areas for development, and the rate and timing of investment, technology development, and infrastructure expansion. This study observed a range of oil projections from less than 80 to 120 million barrels per day in 2030. This wide range results from differing assumptions about these uncertainties.

Biomass, mainly wood and dung burned for heat, is today's largest non-fossil energy source. Liquid fuels from biomass, such as ethanol from corn and sugarcane, have grown rapidly in recent years, but given the scale of total oil consumption, liquids from biomass contribute only about 1 percent of the energy provided by oil. Potential cellulosic biomass resources, from wood, energy crops, and food crop waste, are large in the United States; the U.S. Departments of Agriculture and Energy estimate that the United States could generate sufficient biomass to produce up to 4 million barrels per day of oil-equivalent liquids.[6] As with the expansion of any energy source, challenges must be overcome before biofuels production can achieve significant volumes. For example, technology does not yet exist to convert cellulosic material economically at scale to liquid fuels. Ethanol expansion in the



Source: IEA, *World Energy Outlook 2004*.

FIGURE ES-5. Illustrative Total Liquids Supply

United States faces compound challenges: increasing rail, waterway, and pipeline transport capacity; scaling up distribution systems; and balancing food uses and water requirements.

Wind and solar energy have also grown rapidly, now contributing about 1 percent to the world's energy mix. Wind and solar energy are expected to continue their rapid expansion, with associated challenges that include economics, intermittent availability, land-use considerations, and the need for grid interconnection and long distance transmission lines.

Hydroelectric power supplies about 2 percent of today's energy. It is not generally expected to grow significantly, except in developing Asia-Pacific areas, since the most suitable locations in developed countries are already in use.

Nuclear power contributes about 6 percent of world energy today, and its use is generally expected to increase outside the United States. Nuclear power expansion faces concerns about safety and security, the management and disposal of radioactive waste, and weapons proliferation. Further expansion of nuclear power could be promoted to limit CO_2 emissions or bolster energy security through diversification. On the other hand, additional restrictions on the nuclear industry, such as early plant retirements or limits on projected new installations, would raise demand for alternatives to generate electricity, such as natural gas, coal, wind, and solar.

Coal supplies the second largest share of world energy today, after oil. In forecasts where CO_2 emissions are not constrained, coal is generally expected to increase its share. Projected increases in coal use are driven mainly by growing electricity demand in developing countries. Remaining coal resources are far larger than for oil and natural gas; at current consumption rates, the United States has economically recoverable resources for at least another 100 years.[7] China also has large coal resources, although major deposits are far from consuming areas, and transportation infrastructure is limiting. In addition to the logistical challenges of rail, water, and power lines, coal combustion also produces more CO_2 per unit of energy than natural gas or oil from conventional sources. The combination of coal, natural gas, and oil is generally expected to provide over 80 percent of global energy needs in 2030, exacerbating the challenge of constraining CO_2 emissions.

THE CHANGING WORLD ENERGY MAP

Growth in energy production has been supported by global trade and open markets, combined with capital investment to produce and deliver energy. Energy consumption in the developing world is projected to increase dramatically, while oil and natural gas production in the United States and Europe decline. This combination will require a substantial increase in international oil and natural gas trade, profoundly redrawing the world energy map.

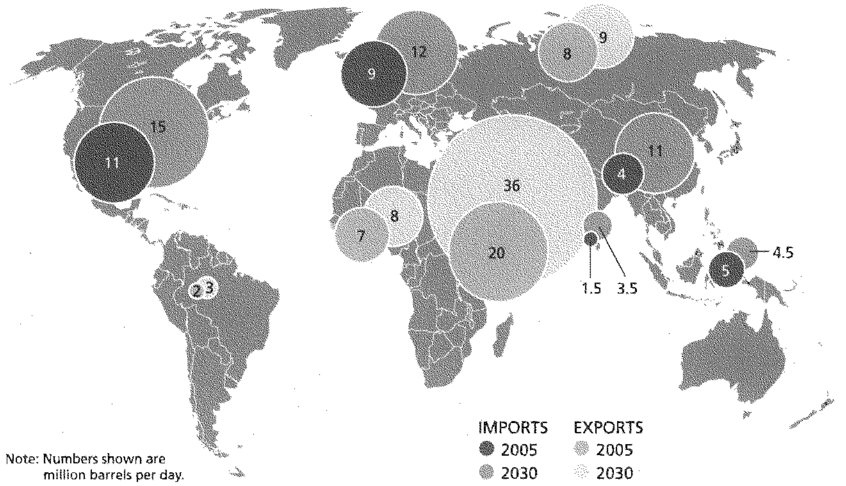
Forecasts for growth in oil and liquefied natural gas (LNG) shipments place greater emphasis on reliable transport, trade, and delivery systems while raising geopolitical, environmental, and security concerns. Today, more than half the world's inter-regional oil movements pass through a handful of potential "choke points," including the Suez Canal, the Bosporus, and the Straits of Hormuz and Malacca.[8]

Figure ES-6 shows one projection of significant changes in regional oil imports and exports between now and 2030. Natural gas supply and demand are projected to make similar shifts.

In addition to increases in the international trade of oil and natural gas, the world energy map is changing in another dimension. Conventional oil and natural gas resources are increasingly concentrated in a handful of non-OECD countries. The national oil companies and energy ministries in these countries play central roles in policy decisions about how to develop and produce their resources. Producers may increasingly leverage their assets when dealing with oil companies and consumer nations, either to gain commercial benefits or to further national or foreign policy objectives. The trend of market liberalization that expanded global energy trade and investment in the 1990s has come under renewed pressure.

UNITED STATES AND GLOBAL ENERGY SECURITY

U.S. and global energy security depend upon reliable, sufficient energy supplies freely traded among nations. This dependence will rise with the growth required in international oil and natural gas trade, and may be increasingly influenced by political goals and tensions. These trends are prompting renewed concerns about U.S. energy security.



Note: Numbers shown are million barrels per day.

Source: IEA, *World Energy Outlook 2006*, Reference Case.

FIGURE ES-6. *Net Regional Oil Imports and Exports*

These energy security concerns have spurred calls for the United States to become totally self-sufficient in energy supply, often referred to as "energy independence." This concept is unrealistic in the foreseeable future and incompatible with broader foreign policy objectives and treaty obligations. Policies espousing "energy independence" may create considerable uncertainty among international trading partners and hinder investment in international energy supply development.[9]

It is a hard truth that energy independence is not necessary for energy security. Rather than pursuing energy independence, the United States should enhance its energy security by moderating demand, expanding and diversifying domestic energy supplies, and strengthening global energy trade and investment. Indeed, even if the United States could become physically self-sufficient in energy, it could not disengage from global energy activity, trade, and finance. There can be no U.S. energy security without global energy security.

INVESTMENT IN GLOBAL ENERGY DEVELOPMENT

Building new, multi-billion-dollar oil platforms in water thousands of feet deep, laying pipelines in difficult terrain and across country borders, expanding refineries, constructing vessels and terminals to ship and store liquefied natural gas, building railroads to transport coal and biomass, and stringing new high-voltage transmission lines from remote wind farms—all will require large investments over decades. Higher investment in real terms will be needed to grow production capacity. Future projects are likely to be more complex and remote, resulting in higher costs per unit of energy produced.[10] A stable and attractive investment climate will be necessary to attract adequate capital for evolution and expansion of the energy infrastructure.

The United States should actively engage energy suppliers, encouraging open trade and investment to expand international energy production and infrastructure. International trade and diplomatic negotiations should routinely incorporate energy issues to promote the rule-of-law, fiscal stability, equitable access, and the environmentally responsible development of all energy resources.

TECHNOLOGY ADVANCEMENTS

Human ingenuity and technological advances create the potential to develop new energy sources, to further develop existing resources, and to use energy in more efficient and environmentally friendly ways. The oil and natural gas industry has a long history of technological advancement, and today it operates using materials, chemistry, engineering, computing, and sensing techniques well beyond anything envisioned several decades ago. Technology has led to large savings in energy demand and additions to supply while reducing the industry's environmental "footprint." Technology advances are expected to continue, although broad-ranging technology impact can take over a decade from initial concept to large-scale implementation.[11]

There is no single technology capable of ensuring that the world's future energy needs will be met in an economical and environmentally responsible way. Many advances and breakthroughs will be required on numerous fronts. To do this, significant financial and human resources must be engaged over a sustained period. Meanwhile, the U.S. energy industry faces a dramatic human resource shortage that could undermine the future development of technological advances needed to meet the demand for increasingly diversified energy sources. A majority of the industry's technical workforce is nearing retirement eligibility, and the number of American graduates in engineering and geosciences has dropped substantially during the last quarter century, compromising future delivery of technology advances.

The Council's findings echo many in the National Academy of Sciences report "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future," which calls for a focus on mathematics and science education, long-term basic research, and ensuring that the United States is the premier place in the world for research and technological innovation.

■ Key Information: Energy Systems Scale and Timeline

The scale of the world energy system and the time required to make significant changes, both on the demand and on the supply sides, are frequently underestimated. A few examples:

- The world currently uses about 86 million barrels per day of oil—40,000 gallons every second.
- New, large oil discoveries can take 15-20 years from exploration until production actually begins, and production can continue for 50 years or more.
- A major new oil platform can cost billions and take a decade or more to complete. The Hibernia platform off the east coast of Canada cost $5 billion, took 19 years from discovery to production, and produces only 0.2 percent of world oil demand.[12] The Thunder Horse platform in the U.S. Gulf of Mexico cost $4 billion, is not yet operating eight years after discovery, and has a capacity of 0.3 percent of world oil demand.[13]
- A new average-sized U.S. refinery (120,000 barrels per day of crude oil distillation capacity) would cost $3 billion or more[14] and would increase U.S. refining capacity less than 1 percent.
- The United States has about 200,000 miles of oil[15] and about 280,000[16] miles of natural gas pipeline, built up over the last century.
- It can take over two decades for a newly commercialized technology to be broadly applied in the vehicle fleet actually on the road—examples include fuel injection and front-wheel drive.
- Buildings typically last for decades. Many of the attributes that affect energy consumption are costly and difficult to retrofit after initial installation, for example wall thickness, insulation, structural tightness, and windows.
- Commercializing new technology in the oil and gas market takes an average of 16 years to progress from concept to widespread commercial adoption.

ADDRESSING CARBON CONSTRAINTS

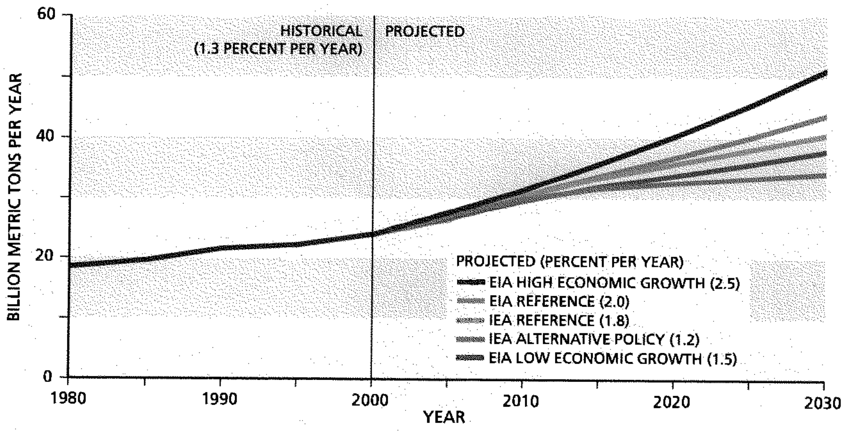
Constraints on CO_2 emissions are emerging, with profound implications for energy supply and demand. Worldwide CO_2 emissions from energy use are generally predicted to grow, as shown in Figure ES-7. Rising concerns about climate change may lead to further limits on these emissions. It is a hard truth that policies aimed at curbing carbon emissions will alter the energy mix, increase energy-related costs, and require reductions in demand growth.

Significantly reducing CO_2 emissions will require major changes in energy production, infrastructure, and use: reducing demand, substituting low-carbon or carbon-neutral fuels, and capturing and sequestering the emissions from burning coal, oil, and natural gas. Implementing effective changes on a sufficient scale will require time, money, and technology. It can take over two decades for newly commercialized vehicle technology to be incorporated into the vehicle fleet actually on the road. Improvements in building efficiency are made slowly—because buildings can stand for many decades, and retrofitting efficiency steps such as increased insulation and better windows can be difficult and costly. Power plants and industrial facilities often last fifty years or more, limiting the rate of capital turnover in these sectors. Achieving any significant increase in efficiency, shift in fuels used, and capture of CO_2 emissions for storage will require major changes over decades to vehicles, buildings, industrial plants, electric generation facilities, and infrastructure.

STRATEGIES FOR U.S. ENERGY POLICY

No single, easy solution can solve the world's energy challenges. The world will need all the economic, environmentally responsible energy sources that can be found to support and sustain prosperity in the coming decades. To assure this, actions on multiple fronts must be taken now, and sustained over the long term. The NPC study participants developed recommendations to achieve the following five strategic goals:

- Moderate demand by increasing energy efficiency
- Expand and diversify U.S. energy supply
- Strengthen global and U.S. energy security



Sources: EIA: U.S. Energy Information Administration, *International Energy Outlook 2006*.
IEA: International Energy Agency, *World Energy Outlook 2006*.

FIGURE ES-7. *World Carbon Dioxide Emissions — Growth Projections*

- Reinforce capabilities to meet new challenges
- Address carbon constraints.

While the focus of this report has been concentrated on identifying key findings and relevant and effective recommendations, it is prudent to be mindful of the lessons of the past. The prospect of unintended consequences or the adverse impacts of poor policy choices should not be underestimated.[17] Policies aimed at penalizing industry segments may have political appeal but often undermine security goals and broader national objectives.

Moderate Demand by Increasing Energy Efficiency

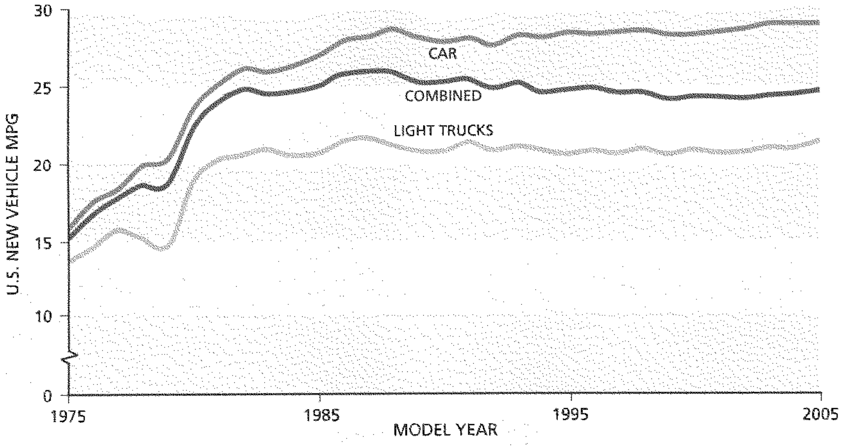
Improve Vehicle Fuel Economy

Nearly half of the 21 million barrels of oil products that the United States consumes each day is gasoline used for cars and light trucks. The Reference Case in the U.S. Energy Information Administration's (EIA) *Annual Energy Outlook 2007* projects that gasoline consumption will increase by an average of 1.3 percent per year, totaling an increase of 3 million barrels per day between 2005 and 2030.

The Corporate Average Fuel Economy (CAFE) standards have been the primary policy used to promote improved car and light-truck fuel economy in the United States over the last three decades. The original standards created one economy requirement for cars, and another less stringent one for light trucks to avoid penalizing users of work trucks. At the time, light-truck sales were about one-quarter of car sales. Since then, sport utility vehicles and minivans classified as light trucks have increased their share of the market. Now, these light-truck sales exceed car sales, and the increase at the lower truck fuel economy standard has limited overall fuel economy improvement.

Cars and trucks sold today are more technically efficient than those sold two decades ago. However, the fuel economy improvements that could have been gained from this technology over the last two decades have been used to increase vehicle weight, horsepower, and to add amenities. Consequently, car and truck fuel economy levels have been about flat for two decades, as shown in Figure ES-8.

Based on a detailed review of technological potential, a doubling of fuel economy of new cars and light trucks by 2030 is possible through the use of existing



Source: U.S. EPA, *Light Duty Automotive Technology and Fuel Economy Trends: 1975 through 2006*.

FIGURE ES-8. *U.S. Car and Light-Truck Fuel Economy* and anticipated technologies, assuming vehicle performance and other attributes remain the same as today.[18] This economy improvement will entail higher vehicle cost. The 4 percent annual gain in CAFE standards starting in 2010 that President George W. Bush suggested in his 2007 State of the Union speech is not inconsistent with a potential doubling of fuel economy for new light duty vehicles by 2030. Depending upon how quickly new vehicle improvements are incorporated in the on-road light duty vehicle fleet, U.S. oil demand would be reduced by about 3-5 million barrels per day in 2030.[19] Additional fuel economy improvements would be possible by reducing vehicle weight, horsepower, and amenities, or by developing more expensive, step-out technologies.

Recommendation

The NPC makes the following recommendations to increase vehicle fuel economy:

- Improve car and light-truck fuel economy standards at the maximum rate possible by applying economic, available technology.
  - Update the standards on a regular basis.
  - Avoid further erosion of fuel economy standards resulting from increased sales of light trucks, or, alternatively, adjust light-truck standards to reflect changes in relative light-truck and car market shares.

Potential Effect: 3-5 million barrels of oil per day in the United States from the increased base in 2030.

Reduce Energy Consumption in the Residential and Commercial Sectors

Forty percent of U.S. energy is consumed in the residential and commercial sectors, including the energy lost while generating and distributing the electricity used. The EIA projects that U.S. residential and commercial energy use will increase almost one-third by 2030.

Significant efficiency improvements have been made in buildings over the last several decades. Improvement areas include the building structure itself; heating, cooling, and lighting systems; and appliances. However, these improvements have been partly offset by increased building sizes and by use of larger and multiple appliances. Cost-effective energy efficiency building technologies have outpaced current U.S. federal, state, and local policies. If applied, currently available efficiency technology would reduce energy use an additional 15-20 percent.[20]

Buildings typically last for decades. Many of the features of buildings that affect their energy consumption, such as wall thickness, insulation, structural tightness, and windows, will go largely unchanged throughout the life of the building. Technologies and practices affecting these long-lived systems will be slow to penetrate the building stock and affect their overall efficiency, making it important to implement policies early to achieve significant long-term savings.

Major barriers to energy efficiency investments include initial costs, insufficient energy price signals, split incentive (where the consumer is different from the facility provider), and individual consumer's limited information. To reduce energy consumption significantly below the projected baseline will require policy-driven improvements in energy efficiency.

Building Energy Codes

Building energy codes have proved to be a significant policy tool to encourage increased energy efficiency in new buildings, and in buildings undergoing major renovations. Building codes are administered by the 50 states and by thousands of local authorities. To help state and local governments, national model energy codes are developed and updated every few years. Under federal law, states are not obligated to impose energy codes for buildings, although at least 41 states have adopted some form of building energy code.

Adopting a building code does not guarantee energy savings. Code enforcement and compliance are also essential. Some jurisdictions have reported that one-third or more of new buildings do not comply with critical energy code requirements for windows and air conditioning equipment, which are among the easiest energy saving features to verify.[21]

Building energy codes typically target only new buildings and major renovations. Additional policies are needed to encourage incremental, significant savings in existing buildings.

Appliance and Equipment Standards

Standards for appliances and other equipment are major policy measures that reduce energy use in existing buildings. These products may not consume much energy individually, but collectively they represent a significant portion of the nation's energy use.[22]

Energy efficiency standards currently do not apply to many increasingly common products, including those based on expanded digital technologies. Product coverage must be continuously evaluated and expanded when appropriate to assure inclusion of all significant energy consuming devices. In addition, industry and other stakeholders have negotiated standards for other products, such as residential furnaces and boilers. Implementing and enforcing expanded and strengthened standards would reduce energy consumption below the levels that will result from current Department of Energy requirements.[23]

Residential and commercial efficiency gains are partially consumed by increased use of the services and products that become more efficient. For example, U.S. house sizes have increased steadily over the years, offsetting much of the energy efficiency improvements that would have resulted had house sizes not swelled. Similarly, household refrigerators have increased in number and size, consuming much of the reduced energy use per refrigerator gained by efficiency standards. Energy efficiency programs should consider steps to avoid increasing the demand for energy services.

Recommendation

The NPC makes the following recommendations to improve efficiency in the residential and commercial sectors:

- Encourage states to implement and enforce more aggressive energy efficiency building codes, updated on a regular basis.
- Establish appliance standards for new products.
- Update federal appliance standards on a regular basis.

Potential Effect: 7-9 quadrillion Btu per year by 2030 in the United States, including 2-3 quadrillion Btu per year of natural gas (5-8 billion cubic feet per day), 4-5 quadrillion Btu per year of coal, and ~1 quadrillion Btu per year (0.5 million barrels per day) of oil.

Increase Industrial Sector Efficiency

The industrial sector consumes about one-third of U.S. energy, and contributes to a large share of the projected growth in both oil and natural gas use globally and in the United States. Worldwide, industrial demand for natural gas is expected to double by 2030. Worldwide, industrial sector demand for oil is expected to increase by 5 million barrels per day, or 15 percent of total oil demand growth through 2030.

The industrial sector is a price-responsive energy consumer. U.S. energy-intensive industries and manufacturers rely on internationally competitive energy supplies to remain globally competitive. In recent years, U.S. natural gas prices have risen faster than those in the rest of the world. As a result, U.S. energy-intensive manufacturers using natural gas as a fuel or feedstock have responded by increasing the efficiency of their operations and/or by shifting more of their operations to lower energy cost regions outside the United States.

Across the industrial sector, there are opportunities to increase energy efficiency by about 15 percent.[24] Areas for energy savings include waste-heat recovery, separation processes, and combined heat and power.[25] While 40 percent of that opportunity could be implemented now, further research, development, demonstration, and deployment are required before the remaining savings can be achieved. Providing programs that encourage deployment of energy efficiency technologies and practices will hasten their implementation. Making the federal research and development tax credit permanent is one way to encourage private investment in these areas. However, a lack of technically trained workers can impede the implementation of efficiency projects while the uncertainty from price volatility can make justifying those projects difficult.

Recommendation

The NPC makes the following recommendations to improve efficiency in the industrial sector:

- The Department of Energy should conduct and promote research, development, demonstration, and deployment of industrial energy efficiency technologies and best practices.

- The research and development tax credit should be permanently extended to spur private research and development investments.

Potential Effect: 4-7 quadrillion Btu per year by 2030 in the United States, about equal parts coal, gas, and oil.

Generation of electricity uses a significant amount of energy. In the United States, about 30 percent of primary energy is used by the electric power generating sector. Only modest generation efficiency improvements appear economically feasible in existing plants (2 to 6 percent), as efficiency improvements are incorporated during routine maintenance. The major potential for efficiency improvement comes when existing generation plants are replaced with facilities using updated technology and designs. Retirement of existing facilities and selection of replacement technology and design is driven by economics affected by fuel cost, plant reliability, and electricity dispatching considerations.

Expand and Diversify U.S. Energy Supply

Oil, natural gas, and coal—the fossil fuels used for transportation, heating, power, and industrial uses—are by far the largest energy sources in industrial economies. While alternative sources, particularly fuel from biomass and other renewables, are likely to contribute increasingly to total energy supply, these three fossil fuels are projected to dominate through at least 2030.

The prospects for oil and natural gas production raise complex questions. It is a hard truth that the global supply of oil and natural gas from the conventional sources relied upon historically is unlikely to meet projected 50-60 percent growth in demand over the next 25 years. There are accumulating risks to replacing current production and increasing supplies of conventional oil and natural gas. They involve a growing set of global uncertainties ranging from production capabilities through environmental constraints, infrastructure needs, and geopolitical complications.

While risks have always typified the energy business, they are now accumulating and converging in new ways. Geopolitical changes coincide with increasingly large and complex technical challenges. Environmental concerns that limit access to some U.S. resources may compete with security concerns that would promote expanded access. Carbon issues challenge coal use while energy security considerations may encourage it. Carbon constraints would require huge capital investments to maintain energy production. These uncertainties, and the risks they generate, describe the background for understanding energy supply prospects during the next few decades.

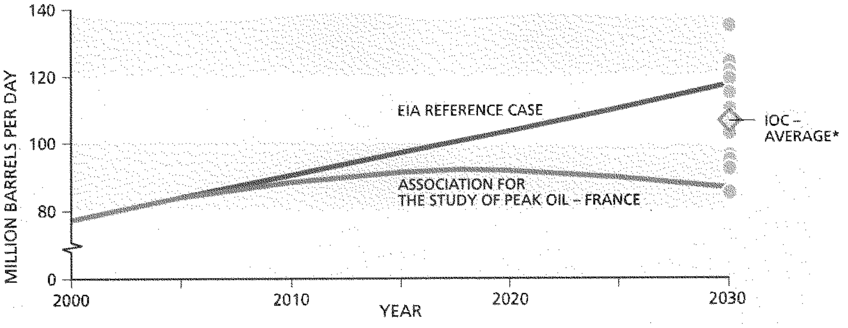
Endowment and recoverable resources are fundamental concepts in any discussion of fossil fuel supplies. *Endowment* refers to the earth's physical store of potential energy sources: barrels of oil, cubic feet of natural gas, and tons of coal. The endowment of fossil fuels is fixed: it can be depleted but not replenished. *Recoverable resources* are a subset of the endowment—the portion that can be produced and converted to fuel and power.

The total global fossil endowment estimates appear huge, but only a fraction of these estimated volumes can be technically produced. The total endowment of oil is estimated at 13-15 trillion barrels, natural gas at 50 quadrillion cubic feet, and coal at 14 trillion tons.

Renewable resources such as biomass, wind, and solar represent huge additional energy endowments that are continuously replenished, unlike fossil fuels.

Understanding the Range of Production Forecasts

This study examined a comprehensive range of oil production forecasts including integrated supply/demand studies from EIA and IEA; publicly available projections from a diverse range of other sources; and a unique set of aggregated proprietary forecasts from international oil companies (IOCs) and energy consulting groups. The diversity of this range of projections is shown in Figure ES-9, which highlights the EIA reference, the Association for the Study of Peak Oil (ASPO) – France, and the average of the IOC forecasts for 2030. The distribution of production forecasts, spanning a range from less than 80 million to more than 120 million barrels per day, highlights the effect of assigning different levels of risk and uncertainty to both resource and above-ground factors. This distribution of outcomes, along with evaluation of assessments of the total resource base, indicates that the key consideration for energy supplies is not endowment



* Average of aggregated proprietary forecasts from international oil companies (IOC) responding to the NPC survey. See Chapter Two (Energy Supply), Analysis of Energy Outlooks, Global Total Liquids Production, for identification of other aggregations and outlooks shown here.

Source: EIA, *International Energy Outlook 2006*, and the NPC Survey of Outlooks.

FIGURE ES-9. *Understanding the Range of Global Oil Forecasts*

but "producibility." Over the next 25 years, risks above ground—geopolitical, technical, and infrastructure—are more likely to affect oil and natural gas production rates than are limitations of the below-ground endowment. This range of outcomes emphasizes the need for proactive strategies to manage the accumulating risks to liquids delivery in 2030.

Explanations for the variance in projections for both conventional oil and natural gas production are widely discussed as part of the "peak oil" debate. As a result, this study sees the need for a new assessment of the global oil and natural gas endowment and resources to provide more current data for the continuing debate.

■ Key Information: The Peak Oil Debate

Concerns about the reliability of production forecasts and estimates of recoverable oil resources raise questions about future oil supply and deliverability. These concerns are strongly expressed in peak oil forecasts in which (1) oil production does not grow significantly beyond current levels and (2) an inevitable decline in oil production is increasingly near at hand. Views about oil supply tend to diverge after 2015, with peak oil forecasts providing the lower bound. These forecasts generally consider oil supply independently of demand and point to supply shortfalls. Such views contrast with forecasts and economic models that expect market forces to provide incentives for developing global hydrocarbon and other resources to meet energy needs through at least 2030.

Forecasts that see an imminent peak in oil production use several indicators to support their case, including: historical peaks in production for individual countries; extrapolations of the production cycle from individual wells to fields, basins, and the world; and the historical dominance of large reservoirs in supplying the world's oil. These historical indicators for production of conventional oil are countered by expectations for new discoveries, enhanced recovery techniques, advancing technology for producing oil from unconventional sources, and reassessments and revisions of known resources. The economic and investment climate, as well as access to resources, will also affect the production base.

For further discussion of peak oil forecasts and related issues, please see Chapter 2, "Energy Supply," in this report.

Reduce Declines in U.S. Conventional Oil and Natural Gas Production

The United States was once the largest oil producer in the world, but is now the third largest daily producer, after Saudi Arabia and Russia. U.S. oil production has declined steadily over the past 35 years, as shown by Figure ES-10. U.S. natural gas production has been more stable, as shown by Figure ES-11, but demand for both oil and natural gas has increased steadily, creating a gap that is filled by imports. Many forecasts project that the gap between supply and demand for domestic oil and natural gas will widen over the next 25 years and beyond. Historically, technology advances have increased the recovery from existing wells and reservoirs. Technology such as enhanced oil recovery (EOR) has the potential to improve recovery factors and reduce declining production.[26]

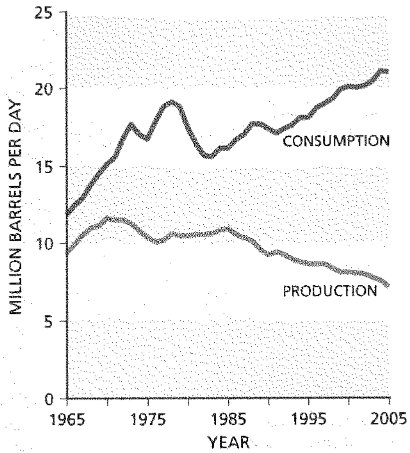
In 2005, over 17 percent of oil and 9 percent of natural gas produced onshore in the United States came from marginal oil wells. The nation has more than 400,000 marginal oil wells[27] each producing on average 2.2 barrels per day. Without these wells, U.S. imports would increase by nearly 7 percent to make up for the shortage. Increasing operational and regulatory costs, and diminishing access to markets via pipelines, are all key factors that can contribute to the premature abandonment of marginal wells. When wells and fields are prematurely abandoned, the associated oil and gas resources may never be recovered due to economics, lease termination, and related issues. Access to existing fields provides the opportunity to deploy new technologies to enhance the ultimate recovery of oil and natural gas from these fields.

Recommendation

The NPC makes the following recommendations to promote enhanced oil recovery (EOR) from existing reservoirs:

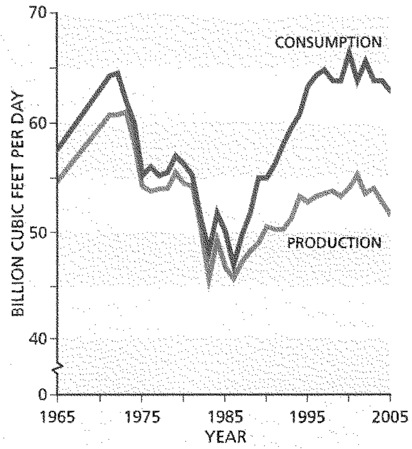
- Support regulatory streamlining and research and development programs for marginal wells.
- Expedite permitting of EOR projects, pipelines, and associated infrastructure.

Potential Effect: An additional 90 to 200 billion barrels of recoverable oil in the United States alone, which could help moderate the current decline in production.



Source: *BP Statistical Review of World Energy 2006.*

FIGURE ES-10. *U.S. Oil Production and Consumption*



Source: *BP Statistical Review of World Energy 2006.*

FIGURE ES-11. *U.S. Natural Gas Production and Consumption*

Increase Access for New Energy Development

For various reasons, access to some domestic energy resources has become restricted. In the United States, an estimated 40 billion barrels of technically recoverable oil resources are either completely off-limits or are subject to significant lease restrictions. These resources are evenly split between onshore and offshore locations, as shown in Figure ES-12. Similar restrictions apply to more than 250 trillion cubic feet of natural gas. Another estimated 11 billion barrels of oil resources and 51 trillion cubic feet of natural gas resources are restricted in Canada. Advancements in technology and operating practices may now be able to alleviate the environmental concerns that originally contributed to some of these access restrictions.

Recommendation

The NPC makes the following recommendations to expand access to the most favorable U.S. oil and natural gas basins:

- Conduct national and regional basin-oriented resource and market assessments to identify opportunities for increasing oil and natural gas supply.
- Use technology and operational advancements to allow environmentally responsible development of high potential onshore and offshore areas currently restricted by moratoria or access limitations.

Potential Effect: Material increases to current reserves within 5 to 10 years from currently inaccessible areas could approach 40 billion barrels of oil and 250 trillion cubic feet of natural gas with current technology.

There is vast potential for oil and natural gas from "unconventional" resources that could be significant contributors to U.S. oil and natural gas production over the next 25 years. Unconventional natural gas exists in formations of "tight" or physically constrained deposits, in coalbeds, and in shale formations. This represents a significant and growing segment of U.S. natural gas production, estimated to be 20-25 percent of current U.S. natural gas production. Typically, unconventional natural gas wells are productive longer than conventional wells, and they can contribute to sustaining supply over a longer period. Similarly, there are large deposits of crude oil in unconventional formations where production is currently increasing with recent technology innovations.

Vast hydrocarbon deposits exist in the oil shales in the Rocky Mountain region of the United States. Until recently, technology has been unavailable to produce these oil shale deposits at a competitive cost and with acceptable environmental impact. Research, development, and demonstration programs are increasing to advance the technologies required to expand economically and environmentally sustainable resource production. However, successful production at scale may still be several decades away.

Recommendation

The NPC makes the following recommendations to increase unconventional oil and natural gas production:

- Accelerate U.S. oil shale and oil sands research and development and leasing.
- Accelerate U.S. unconventional natural gas leasing and development.

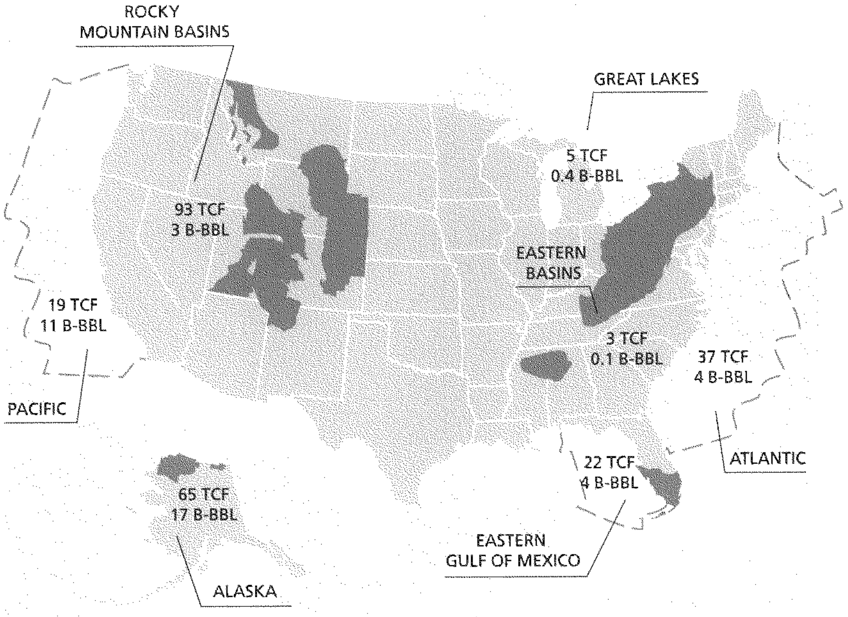
Potential Effect: Double U.S. unconventional natural gas production to more than 10 billion cubic feet per day, increasing total U.S. natural gas production by about 10 percent.

Implementing these strategies can slow the inevitable decline in U.S. oil and natural gas production, but is unlikely to reverse it. The gap between U.S. production and demand will continue to widen, particularly for oil. Long lead-times and higher capital requirements to develop economical energy from new or remote locales, and from unconventional oil and natural gas resources, all contribute to the challenge of moderating the U.S. production decline.

Diversify Long-Term Energy Production

Accelerate the Development of Energy from Biomass

As total U.S. energy demand grows, there will be an increasing need to supplement energy supplies



Note: TCF = Trillion Cubic Feet; B-BBL = Billion Barrels.
Source: U.S. Department of the Interior.

FIGURE ES-12. *U.S. Oil and Natural Gas Resources Affected by Access Restrictions*

with diversified domestic energy sources that are economically and environmentally viable and can be developed at commercial scale. Coal and nuclear power already play a significant role, and biomass is emerging as an option, primarily for conversion to transportation fuels. Wind and solar energy are forecast to grow faster than overall energy demand, although their total projected contribution will remain small over this study period. Taken together, all these energy sources can contribute to reducing risks posed to energy supply security.

Biomass includes wood, cultivated crops, and naturally growing vegetation that potentially can be converted to energy sources. First-generation biomass conversion to fuels has been based on crops like corn, sugarcane, soybeans, and palm oil. Developing second-generation biomass conversion technologies, such as cellulosic ethanol, which would use trees, energy crops, and plant waste as a feedstock, could allow non-food vegetation to become a significant resource for fuel production.

As with any newly developed energy sources, certain technical, logistical, and market requirements must be met for biofuels to achieve significant scale. Challenges include: expanding rail, waterway, and pipeline transportation; scaling up ethanol production plants and distribution systems; developing successful cellulosic ethanol conversion technology; and maximizing the potential of arable land.

Recommendation

The NPC makes the following recommendations to accelerate development of biomass energy sources at large commercial scale:

- Support research into second-generation biofuel crops that have lower input requirements or are suited to more marginal lands.
- Promote agricultural policies that enhance global production of both food crops and biomass for fuel.
- Support policies that promote the development of the infrastructure for harvesting, storing, and transporting energy crops, and facilitate the integration of biofuels into the national transportation fuel supply.

Potential Effect: Increase U.S. production by up to 4 million barrels per day of oil-equivalent liquids.[18]

Enable the Long-Term Environmental Viability of Coal for Power, Fuel, and Feedstock

Given the vast coal resource base in the United States—by some estimates, the world's largest—and the major contribution that coal makes to electricity generation today, coal needs to remain a viable long-term component of U.S. energy supply. Many studies forecast growth in coal use for power, plus additional growth for direct conversion of coal to liquids to diversify the fuel supply. However, coal combustion is also the largest source of CO_2 emissions from energy production. Adding coal-to-liquids production at scale, as with conversion of most heavy unconventional hydrocarbons, would generate large additional CO_2 volumes. Therefore, addressing carbon constraints at scale will likely be an essential requirement for retaining coal as a viable part of the energy supply system. Recommendations for maintaining coal's long-term viability are discussed specifically in the section entitled "Address Carbon Constraints" later in this Executive Summary.

Expand Domestic Nuclear Capability

Energy projections generally show a continuing role for nuclear energy, notwithstanding concerns about safety, security, radioactive waste, and weapons proliferation. In a carbon constrained environment, nuclear energy may need to become a much larger part of the energy mix. Nuclear energy must remain viable over the 25 years considered in this study—both to meet projected demand and to provide expanded capacity, if necessary, to reduce CO_2 emissions.

Recommendation

The NPC makes the following recommendations to expand the domestic technical and industrial capabilities of the nuclear energy/power industry:

- Implement the recommendation by the National Commission on Energy Policy[19] to provide $2 billion over ten years from federal energy research, development, demonstration, and deployment budgets for demonstration of one to two new advanced nuclear facilities.
- Fulfill existing federal commitments on nuclear waste management.

Potential Effect: Reestablish U.S. leadership capability. Maintaining a viable nuclear energy option will increase policy choices in future carbon constrained circumstances.

Strengthen Global and U.S. Energy Security

Besides expanding U.S. oil and natural gas production and developing additional domestic energy types at commercial scale, it will be necessary to enlarge and diversify oil and natural gas supplies from global markets. The long lead-times needed to build domestic energy alternatives at commercial scale will require the United States to remain engaged in international energy markets beyond the time frame considered in this study. Moreover, oil and natural gas supplies from major resource-

Key Information: Energy Security and Strategic Petroleum Stocks

This study examined the long-term energy future and focused on fundamental supply and demand, since a robust supply/demand balance is necessary for global energy security. In the short term, there is another aspect to energy security—the availability of strategic stocks to respond to a short-term disruption in supplies.

Following the oil supply shocks of 1973-74, the OECD countries agreed to maintain strategic petroleum stocks and created the International Energy Agency to coordinate measures in times of oil supply emergencies. Today, OECD countries are committed to individually hold oil stocks equal to 90 days of their imports.

This strategic stockholding proved its worth in the aftermath of Hurricanes Katrina and Rita in the U.S. Gulf of Mexico in the fall of 2005. At one point, the hurricanes shut down all Gulf Coast crude oil production and nearly 30 percent of U.S. refining capacity. The IEA coordinated a release of oil from stockpiles worldwide, and the global market quickly rebalanced, with the United States receiving petroleum product supplies from around the world—including Europe and Japan.

In total, the OECD countries currently hold about 1.4 billion barrels of strategic oil stocks. The U.S. Strategic Petroleum Reserve (SPR) alone holds nearly 700 million barrels of crude oil today. To put the U.S. SPR in perspective, its volume currently represents sixteen months of United States oil imports from Venezuela.

The total OECD strategic stockpile volume represents almost 18 months of the entire volume of Iranian crude oil exports (none of which are currently imported into the United States).

holding countries often bear lower production and development costs than do U.S. domestic sources. Maintaining U.S. access to these sources will contribute to an affordable U.S. energy supply and promote U.S. competitiveness in the global marketplace.

The world is entering a period in which international energy development and trade are likely to be influenced more by geopolitical considerations and less by the free play of open markets and traditional commercial interactions among international energy companies. Global competition for oil and natural gas will likely intensify as demand grows, as new parties enter the market, as some suppliers seek to exploit their resources for political ends, and as consumers explore new ways to guarantee their sources of supply.

These shifts pose profound implications for U.S. interests, strategies, and policy making as well as for the ways that energy companies conduct business. Many of the expected changes could heighten risks to U.S. energy security in a world where U.S. influence is likely to decline as economic power shifts to other nations. In years to come, security threats to the world's main sources of oil and natural gas may worsen.

In geoeconomic terms, the biggest impact will come from increasing demand for oil and natural gas from developing countries. This demand may outpace timely development of new supply sources, thereby pressuring prices to rise. In geopolitical terms, the consequences of shifting the balance between developed and developing countries will be magnified by the accelerating demand coming most strongly from China, India, and other emerging economies.

These developments are taking place against a background of rising hostility to globalization in large parts of the world, including in many industrialized countries that benefit from it. This hostility could possibly fracture the global trading system. The political will to complete multilateral trade negotiations may be ebbing as major producers and consumers seek bilateral or regional preferential agreements that can fragment world trade, increase costs, and diminish market efficiency.

Recommendation

The NPC makes the following recommendations to promote global and U.S. energy security:

- Integrate energy policy into trade, economic, environmental, security, and foreign policies by having the Department of Energy share an equal role with the Departments of Defense, State, Treasury, and Commerce on policy issues relating to energy and energy security.
- Continue to develop the international energy marketplace by expanding the energy dialogue with major consuming and producing nations, including China, India, Canada, Mexico, Russia, and Saudi Arabia.
- Promote an effective global energy marketplace by sustaining and intensifying efforts to encourage global adoption of transparent, market-based approaches to energy through multilateral and international institutions—including the World Trade Organization, G8, Asia-Pacific Economic Cooperation (APEC), IEA, International Energy Forum, and the Joint Oil Data Initiative (JODI).
- Assist and encourage global adoption of energy efficiency technologies through technology transfer programs and lend-lease arrangements.

Potential Effect: Restricted resource access and curtailed production could put potential 2030 global liquid (25-35+ million barrels per day) and gas (150-200+ billion cubic feet per day) incremental growth at risk.

Reinforce Capabilities to Meet New Challenges

To meet the world's growing energy needs, critical capabilities for delivering energy supplies will need to be improved. These critical capabilities include:

- Assessing future infrastructure requirements
- Developing human resources
- Encouraging technology advancement
- Enhancing the quality of energy data and information, including expanding knowledge of resource endowments.

Develop a Comprehensive Forecast of U.S. Infrastructure Requirements

Transportation infrastructure plays a vital role in delivering energy and other commodities from resource locations to shipping centers, to manufacturing plants for processing, and ultimately to demand centers for consumption. The transportation system as a whole is an immense network of pipelines, railways, waterways, ports, terminals, and roadways that has evolved over the past two centuries. The system today is a highly complex, robust delivery network that operates in a safe, reliable manner and serves as the foundation for the country's economic activity.

Shipments of goods have increased substantially using all modes of transport. The spare capacity and redundancies in the various infrastructure systems that existed 25 to 30 years ago have diminished. Continuing growth will require additions to infrastructure.

New infrastructure investments will also be required as nontraditional energy sources grow. Infrastructure requirements for many alternative energy sources, such as biofuels and unconventional oil and natural gas, will be significant and yet are often underestimated. The potential scale of CCS activities would also require significant new infrastructure.

Energy supply and demand projections to 2030 generally assume infrastructure will be built if it is economic to do so. These forecasts generally assume no constraints on the ability to finance, permit, and build the infrastructure required to supply increasing kinds and amounts of energy. In practice, however, social, environmental, and land-use constraints do affect infrastructure planning and development. Complex permitting processes lengthen the time and cost of infrastructure construction and maintenance or may entirely preclude the infrastructure needed for certain energy options. Additional information is needed to understand the full requirements for energy infrastructure additions and the potential limitations to timely investment.

Recommendation

The NPC makes the following recommendations to improve understanding of infrastructure needs to meet future U.S. energy system growth:

- **The Department of Energy (DOE) should develop an integrated study of the energy infrastructure needs to 2030.**
- **The EIA should incorporate infrastructure-related data into its energy information collection system.**

Rebuild U.S. Science and Engineering Capabilities

As the post-World-War-II baby-boom generation begins to retire, the energy industry faces a severe human resource challenge. Nearly half of personnel in the U.S. energy industries will be eligible for retirement within the next 10 years, and fewer people have entered the workforce over the past generation. A "demographic cliff" is looming in all areas of energy industry employment.[31] A hard truth is that the U.S. energy workforce must be replenished and trained, although too few young people are preparing for the opportunities.

An American Petroleum Institute survey in 2004 indicated that by 2009 there will be a 38-percent shortage of engineers and geoscientists and a 28-percent shortage of instrumentation and electrical workers in the U.S. oil and gas industry. Statistics for other science, engineering, and technology professions specifically within the energy industry are not available, but the problem extends to those areas as well. One of the more important predictors for the future supply of potential employees in oil and natural gas is the number of students earning university degrees in petroleum engineering and geosciences. Enrollment in these petrotechnical programs has dropped about 75 percent over the last quarter-century.

The United States has traditionally been a leader in the global energy industry, but that position is threatened by the anticipated loss of experience through retirements, without adequate replacements. The U.S. government and the energy industry should work actively to renew this vital workforce through education, recruitment, development, and retention—much as companies strive to develop and renew energy supplies.

Federal and state governments can play an important role by funding university research and development in science and technology. Consistent support for university research programs relating to the energy industry will signal prospective students that these subjects are vital to the country. For example, several universities have recently increased petrotechnical enrollment by active recruiting aimed at high school seniors, their parents, and their counselors. These results indicate that vigorous recruiting can yield positive results, but efforts need to be more widespread.

Recommendation

The NPC makes the following recommendation to enhance U.S. science and technical education programs:

- **Provide support to those seeking engineering and other technical degrees, both undergraduate and graduate, by increasing scholarships and research funding at universities and support for technical schools.**

There is insufficient time to train enough young professionals to fill the positions opening over the next decade. Accelerating competencies through knowledge sharing, coaching, and mentoring will become critical. Many retirees might prefer to phase-in retirement, but face regulatory barriers that restrict their part-time work. These individuals' expertise should be harnessed to prepare the next generation in both professional and vocational training programs.

Recommendation

The NPC makes the following recommendations to make it easier for retirees to continue working as consultants, teachers, and coaches:

- **Modify the U.S. tax code and retirement plan regulations to allow part-time work after retirement without penalty.**

Across continents, there is a geographical disparity in the supply of new graduates for some energy related fields (Figure ES-13). Over the next ten years, the number of foreign nationals allowed to work in the United States will be restricted by the number of work permits issued each year. Increasing the quotas on work and study permits can help alleviate this geographical imbalance, and support U.S. energy productivity.

Recommendation

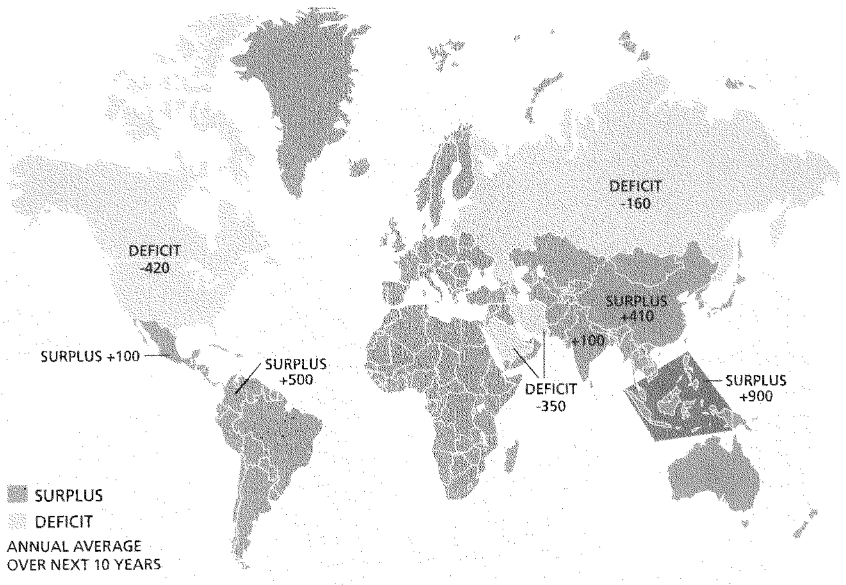
The NPC makes the following recommendation to increase the supply of trained energy professionals in the United States:

- **Increase student and immigration quotas for trained professionals in energy and technical fields.**

Create Research and Development Opportunities

The oil and natural gas industry uses advanced, state-of-the-art technology. Exploration specialists interpret geologic structures miles beneath the earth's surface. Drilling engineers access the resources found at extreme depths, at high temperature and pressure, and often in remote and physically challenging places. Production engineers bring the oil and natural gas to the surface through miles of pipeline, also under sometimes extreme conditions, and deliver them to refineries. Once there, increasingly heavy and sulfurous crude oils are refined into useful products. All these accomplishments are achieved today with a smaller environmental "footprint" than even a decade ago, and are conducted more economically than ever before.

Most energy technology is developed by industry in response to a resource opportunity, such as opening



Source: Schlumberger Business Consulting study, 2005.

FIGURE ES-13. *The Regional Imbalance of Petrotechnical Graduates* exploration in the deepwater Gulf of Mexico. Fewer investments are being directed to researching possibilities for energy production in the continental United States, where accessible conventional opportunities are maturing. Government has a role in creating new opportunities and developing the regulatory framework and infrastructure needed to extract new resources. Enhanced oil recovery is an activity for which funding by the DOE for research could pay significant dividends through increased domestic production. Coalbed methane and oil shale present additional opportunities.

The decline in DOE-funded oil and natural gas-related research and development in the past two years has affected both universities and the National Laboratories. Government funding in engineering and science, when distributed to universities and National Laboratories, sustains these important institutions. It is vital that this funding is accompanied by contracts that call for spending accountability and research delivery.

The national interest is also well served when the government supports large-scale demonstration projects, such as the FutureGen program to integrate large-scale electricity generation with carbon capture and sequestration. In addition, government and industry would benefit from collaborating in several critical areas, including advanced materials, bioprocess, and meteorological and oceanic (metocean) research.

Recommendation

The NPC makes the following recommendations to expand research and development opportunities to support long-term study goals:

- Review the current DOE research and development portfolio to refocus spending on innovative, applied research in areas such as EOR, unconventional oil and natural gas, biofuels, nuclear energy, coal-to-fuels, and CCS.
- Maintain a fundamental research budget in the DOE Office of Science to support novel technologies.
- Focus and enhance research in the U.S. universities and National Laboratories.
- Encourage DOE, Department of Defense, and industry cooperation in innovative areas of development, such as advanced materials and metocean information and analyses.

Improve the Quality of Energy Data and Information

As the study teams examined multiple forecasts, they observed that some of the important basic data and information were incomplete, inconsistent, dated, or oversimplified. Investment and policy decisions are increasingly informed by such uncertain data. For example, some disparities in predictions for future oil and natural gas supplies result from divergent estimates of the underlying resources and their deliverability. Additionally, little or no quantitative data are available to clearly understand the need for additional infrastructure capacity.

Recommendation

The NPC makes the following recommendations to enhance the quality of energy data and information:

- Expand data collected by EIA and IEA to provide additional sources of production and consumption data for inclusion in annually prepared public domain energy outlooks.
- Expand funding for data collection and analysis of energy transportation systems to enable informed infrastructure decisions.

There are many energy outlooks, but most base their projections for future fossil-fuel production on a few publicly available resource estimates, most notably the U.S. Geological Survey (USGS) assessments. Since these assessments are comprehensively updated only every decade or so, the fundamental data for energy policy decisions may not reflect the most current perspectives. In addition, the many organizations involved in energy forecasting and analysis often apply different methodologies and assumptions to the assessments, which can create misunderstandings about future production capabilities.

This study's results confirm the primary importance of maintaining comprehensive, up-to-date, fundamental assessments of the global oil, natural gas, and coal endowment and recoverable resources. Although each such assessment produces inherent uncertainties based on the state of geological knowledge and observational information, a new, comprehensive assessment would more accurately frame the condition of the fossil resource base for policy decision making and strategy. Additionally, given the growing contribution expected from biomass-based energy sources by 2030, a global assessment of this renewable resource would provide a more complete outlook for the available energy endowment.

In order to increase the reliability and timeliness of fundamental endowment and resource data, the United States should collaborate with other global stakeholders to improve the collection, management, interpretation, and communication of data and estimates for energy endowments and recoverable resources.

Recommendation

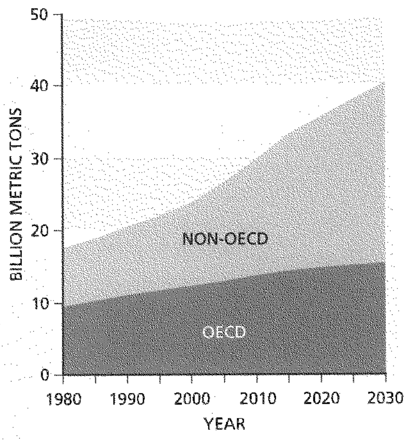
The NPC makes the following recommendations to update publicly available global endowment and resource estimates:

- The USGS should conduct a comprehensive geological assessment of U.S. and global oil and natural gas endowment and recoverable resources.
  - Incorporate wider participation of industry and international experts and current data.
- The USGS should conduct a new comprehensive survey of U.S. and global recoverable coal resources and reserves using common analysis and reporting methodologies.
- The U.S. Departments of Energy and Agriculture should conduct a global biomass resource assessment.

Potential Effect: Timely and better informed policy decisions based on shared understanding of critical resource data.

Address Carbon Constraints

There is growing concern that the global climate is warming, and that CO_2 emissions from human activity play a role. The NPC did not examine the science of climate change. But recognizing that an increasing number of initiatives to reduce these emissions are emerging, the NPC considered the potential effect of CO_2 emissions constraints on energy and opportunities for technology application. Limits on CO_2 emissions could restrict fossil fuel use, which currently provides more than 80 percent of the world's energy. Therefore, it is increasingly important to plan for potential constraints on CO_2 emissions as part of any overall energy strategy.



Source: IEA, *World Energy Outlook 2006*, Reference Case.

FIGURE ES-14. *World Carbon Dioxide Emissions*

By its nature, climate change is global. CO_2 emissions from burning fossil fuels contribute to the overall flux of carbon between the atmosphere, the land, and the oceans. By mixing in the atmosphere, CO_2 emitted anywhere in the world is distributed around the globe.

The United States was the world's largest CO_2 emitter from energy use as of 2005,[32] both in total emissions and on a per-capita basis, but most projected growth of CO_2 emissions is in the developing world, as illustrated in Figure ES-14. Significantly reducing CO_2 emissions would require global, broad-based actions over decades, with major and sustained investment.

Enable Carbon Capture and Sequestration

Coal combustion is the largest source of CO_2 emissions from energy use, and coal is projected to remain a major fuel for electricity generation in most forecasts. The resource base for coal is much larger than that for oil and natural gas, and the United States has the world's largest coal resource by some estimates.[33] One opportunity for reducing CO_2 emissions is carbon capture and sequestration, which traps CO2 and stores it underground. Extensive, commercial scale deployment of this technology could allow continued coal use in a carbon constrained future. Additionally, some unconventional oil production requires substantial energy, increasing CO_2 emissions per unit of delivered energy, and future development could be influenced by the availability of CCS. An initial suite of technologies for large-scale CCS implementation already exists within the oil and natural gas industry, although such technologies have yet to be demonstrated in combination and at commercial scale. More importantly, a legal and regulatory framework for long-term CO_2 storage is still lacking.

Scale is also a major consideration for CCS. In the United States, if all the CO_2 from today's coal-fired electricity generation were collected and compressed, it would total 50 million barrels per day.[34] This amounts to 2½ times the volume of oil handled daily in the United States. To accommodate such volumes, potential storage sites need to be mapped and assessed.

Recommendation

The NPC makes the following recommendations to enable long-term environmental viability of coal for both power and fuels.

- Establish a legal and regulatory framework which is conducive to CCS.
  - Provide regulatory clarity for land use and liability policies.
  - Provide access to federal lands for storage.
- Enable full scale CCS and clean coal technology demonstration.
  - Organize efforts between the power and oil/natural gas industries.
- Undertake a national CO_2 sequestration capacity assessment.
  - Build on the existing efforts being undertaken by the DOE Regional Partnerships.
  - Encourage global application.

  - Continue federal research and development support for advanced coal-to-fuel technologies.

Potential Effect: Maintaining coal's projected 25 percent contribution to the future U.S. energy mix, including potential coal-to-liquids production, even in carbon-constrained circumstances.

A comprehensive approach to carbon management would include measures to: boost energy efficiency and reduce demand; increase use of power that is not carbon based (nuclear, wind, solar, tidal, ocean-thermal, and geo-thermal); shift to lower carbon fuels, including renewables; and deploy CCS. Putting a cost on carbon emissions across all economic sectors, whether through a carbon tax or a carbon cap-and-trade mechanism, would allow the marketplace to find the lowest cost combination of steps to achieve carbon reduction. Any cost should be imposed in a predictable manner over the long term, since regulatory uncertainty weakens the investment climate and has the potential to disrupt economic activity. Any cost imposed should also consider the actions of other countries and the resulting effect on U.S. competitiveness.

Recommendation

As policymakers consider actions to reduce CO_2 emissions, the NPC recommends including:

- An effective global framework for carbon management incorporating all major emitters of CO_2 and focusing particularly on opportunities for U.S.–China cooperation.
- A U.S. mechanism for setting an effective cost for emitting CO_2 that is:
  - Economy-wide, market-based, visible, transparent, applicable to all fuels.
  - Predictable over the long term for a stable investment climate.
- A credit for CO_2 used in enhanced oil and natural gas recovery.

Key Information: Policy Avenues to Limit Carbon Dioxide Emissions

Direct regulation: CO_2 emissions could be constrained by imposing limits on emissions from individual sources, such as power plants and industrial facilities. Economists generally regard this sort of regulation as inefficient, because it does not allow for the likelihood that some sources may be able to achieve emissions reductions more economically than others. Encouraging greater emissions reductions by the sources that can do so most economically would yield a larger total reduction for a given total cost, but this can be difficult to accomplish with fixed regulatory targets.

Cap-and-trade regulation: Cap-and-trade systems seek to overcome the inefficiency of direct regulation by providing a market-based mechanism to encourage those who can reduce CO_2 emissions most economically to do so. Regulators must determine which sources will be covered by the system and the total amount of emissions that will be allowed within a specified period of time. Permits to emit a given amount, such as one metric ton of CO_2, are then allocated or auctioned. The permits can be traded, encouraging sources that can eliminate emissions for less than the market price of a permit to do so, while sources for whom emissions control is more costly can buy permits from others.

Creating a cap-and-trade system involves important policy choices:

- Which sectors to include.
- What level of emissions should be permitted and whether any "safety valve" is provided to limit the volatility or price of permits.
- Whether permits should be allocated at no cost or auctioned.
- Whether there should be a single permitting system covering all affected sectors or multiple systems for different sectors.

Fundamentally, a cap-and-trade system establishes a level of emissions, and the marketplace then establishes the cost.

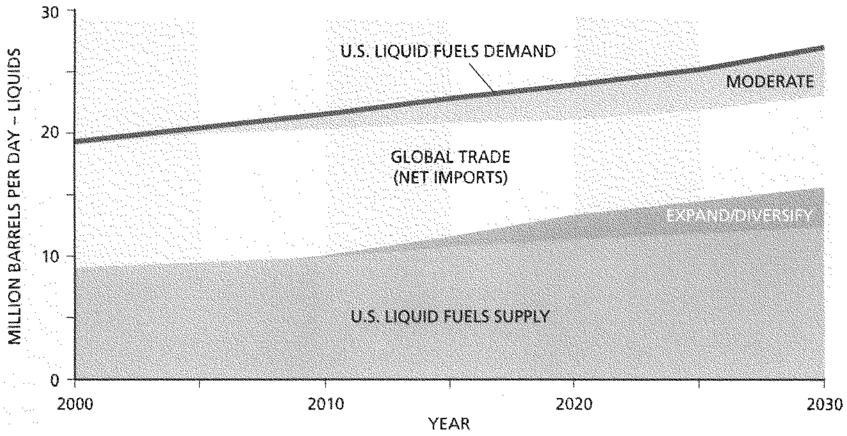
Carbon taxes or fees: A tax or fee could be levied on CO_2 emissions, establishing the cost of emissions while letting the market then establish the emissions level. In principle, any level of emissions reduction that could be achieved with a cap-and-trade scheme could also be achieved with taxes or fees. For CO_2 emissions from combustion, the simplest method would levy the fee on the primary fuel, with a credit system for any use that doesn't emit CO_2, such as production of petrochemicals.

A tax or fee system has the advantages of establishing a predictable cost, thus encouraging long-term planning and investment, and not requiring the regulatory complexity of determining the equitable emissions allowance levels by sector and facility. A tax or fee system has the disadvantage that the level of resulting emissions is not established in advance. A tax or fee system also poses the challenge of how to equitably return the revenues to the economy.

Potential Effect of Recommended Strategies

The Council proposes five core strategies to assist markets in meeting the energy challenges to 2030 and beyond. An illustration of the potential effect of implementing all the recommended strategies is shown in Figure ES-15. Starting with the EIA Reference Case for U.S. liquid fuel demand, the potential effect of the recommended demand reduction strategies is shown in light green. The potential effects of recommended strategies to moderate the decline of conventional supplies, and strategies to further expand and diversify supplies are shown in dark green. The combined effect of the recommended strategies would reduce the gap between domestic demand and supply by about one-third from 2006 to 2030 in this illustration—improving the outlook for energy availability, reliability, cost, and environmental impact.

Given the massive scale of the global energy system and the long lead-times necessary to make significant changes, concerted actions to implement these recommendations must be taken now, and sustained over the long term, to promote U.S. competitiveness



Source: EIA, *International Energy Outlook 2006*, Reference Case / NPC Global Oil and Gas study estimates.

FIGURE ES-15. *Illustrative Effect of Recommended Strategies for the United States*

by balancing economic, security, and environmental goals. The following report chapters detail more fully the challenges posed by the complexity of the world's integrated energy system and the opportunities to secure a more reliable energy future.

Endnotes

1 The OECD (Organisation for Economic Co-operation and Development) includes Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States of America.

2 For 2003, per the IEA's *World Energy Outlook 2005* and the EIA's *International Energy Outlook 2006*.

3 As of year-end 2005, 31.6 million cars and 1.3 billion people, as reported by the China National Statistics Bureau.

4 Per the U.S Bureau of Transportation Statistics, the United States had 137 million cars in 2004; population was 281 million. But the U.S. also has a large number of trucks/SUVs used as passenger vehicles, which are unfortunately not reported separately. A close approximation would be the category of "other vehicles—two axle, four wheel," which would add 92 million vehicles and bring the total for U.S. "passenger vehicles" to 228 million, for a ratio of 8 passenger vehicles for 10 people.

5 "Primary Energy" refers to first use of an energy source. For example, coal can be burned to produce electricity. There are losses of energy in the process of generating and transmitting the electricity to the end user, such that the energy value of electricity finally used is less than the energy value of the coal initially burned. In this example, coal is the primary energy, not the final electricity used.

6 The "Billion Ton Study" – *Biomass as a Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*, USDA and USDOE, April 2005, available at http://www.osti.gov/bridge.

7 About 240 years based on the most recent study by USGS in 1974. Just prior to publication of this NPC study, the National Academy of Sciences issued a report suggesting that economically recoverable coal reserves in the U.S. might be lower than the 1974 USGS study—approximately 100 years of current consumption.

8 See in this report, "New Patterns of Trade" section in Chapter 4, Geopolitics.

9 See *World Oil Outlook 2007*, OPEC Secretariat, especially pages 2, 7, and 8.

10 IEA *World Energy Outlook 2006*, Chapter 12, page 315.

11 Refer to the *Technology Development Topic Report* accompanying this report, Section F.

12 The Hibernia platform discovery in 1979, first production in 1997, producing 180,000 barrels per day. *http://www.hibernia.ca*

13 The Thunder Horse Platform discovery in 1999, design capacity 250,000 barrels per day. *http://www.bp.com*

14 Per reported estimates for a proposed new refinery by the Arizona Refining Company, *http://www.arizonacleanfuels.com*

15 American Association of Oil Pipelines.

16 National Petroleum Council, *Balancing Natural Gas Policy*, 2003.

17 For example, see *The Crude Oil Windfall Profit Tax of the 1980s—Implications for Current Energy Policy*, Congressional Research Service, 2006, available at http://nationaljournal.com/policy-council/energy/legnar/031406CRS_Crude.pdf.

18 See in this report, "Transportation Efficiency" section of Chapter 3, Technology. The extent to which technologies translate into reductions in fuel consumption depends on several factors, including costs, consumer preferences, availability, deployment, and timing.

19 The potential fuel savings of 3 to 5 million barrels per day in 2030 is relative to a scenario where current fuel economy standards remain unchanged through 2030.

20 Baseline projections taken from Energy Information Administration, *Annual Energy Outlook 2007 with Projections to 2030*, Table 2, February 2007, http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_2.xls; savings estimates taken from several studies including *Building on Success, Policies to Beduce Energy Waste in Buildings*, Joe Loper, Lowell Ungar, David Weitz and Harry Misuriello – Alliance to Save Energy, July 2005. "Achievable" used here means that the measures are currently available and the savings can be realized with a reasonable level of effort and with acceptable reductions, if any, in perceived amenity value.

For additional discussion, see the *National Action Plan for Energy Efficiency*, which is available at: http://www.epa.gov/cleanrgy/actionplan/eeactionplan.htm.

21 From *Building on Success, Policies to Reduce Energy Waste in Buildings*, Joe Loper, Lowell Ungar, David Weitz and Harry Misuriello – Alliance to Save Energy, July 2005, pp. 18-19. For a compilation of compliance studies, see U.S. Department of Energy, *Baseline Studies*, on web site (http://www.energycodes.gov/implement/baseline_studies.stm). Arkansas reports 36 of 100 homes in the study sample did not meet the HVAC requirements of the state energy code.

22 From *Building on Success, Policies to Reduce Energy Waste in Buildings*, Joe Loper, Lowell Ungar, David Weitz and Harry Misuriello – Alliance to Save Energy, July 2005, p. 24.

23 For additional savings potential see Steven Nadel, Andrew deLaski, Maggie Eldridge, & Jim Kleisch, *Leading the Way: Continued Opportunities for New State Appliance and Equipment Efficiency Standards*, March 2006, http://www.standardsasap.org/a062.pdf.

24 From the *Chemical Bandwidth Study*, DOE, 2004; *Energy Bandwidth for Petroleum Refining Processes*, DOE, 2006; *Pulp and Paper Industry Energy Bandwidth Study*, AIChE, 2006.

See also *Curbing Global Energy Demand Growth: The Energy Productivity Opportunity*, McKinsey Global Institute, May 2007.

25 "Combined heat and power" refers to using the excess heat from generating electricity to meet processing or building heat needs. This combination is frequently called "cogeneration" and results in a substantial increase in efficiency versus generating electricity and heat separately.

26 See in this report, "Conventional Oil" section in Chapter 3, Technology, for a full discussion of potential technologies that may increase conventional oil and gas recovery.

27 A "marginal well" is one that produces less than 10 barrels of oil per day.

28 The "Billion Ton Study" – *Biomass as a Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*, USDA and USDOE, April 2005, available at http://www.osti.gov/bridge.

29 See www.energycommission.org/files/contentFiles/report_noninteractive_44566feaabc5d.pdf, page IV.

30 Iranian oil exports were 2.5 million barrels per day in 2006 per the EIA.

31 U.S. Department of Labor: "Identifying and Addressing Workforce Challenges in America's Energy Industry," President's High Growth Job Training Initiative, U.S. DOL Employment Training Administration (March 2007).

32 According to a preliminary estimate by the Netherlands Environmental Assessment Agency, China overtook the United States in total CO$_2$ emissions for the year 2006. More information at http://www.mnp.nl/en/dossiers/Climatechange/moreinfo/Chinanowno1inCO2emissionsUSAinsecondposition.html.

33 Based on the 1974 USGS assessment. A very recent study by the National Academy of Science suggests that the U.S. economically recoverable coal resource may only be ~40% of the USGS estimate.

34 Based on 150,000 barrels per day of supercritical CO$_2$ from a one-gigawatt coal-fired power plant and 2,090 terawatt-hours of coal-fired electricity generation in the United States in 2004 per the EIA.

Chapter 1

ENERGY DEMAND

Abstract

Demand for energy is growing steadily, and is likely to reach increasingly higher levels as populations and economies expand. During the last quarter-century, world energy demand increased by over half, and a similar increase is projected between now and 2030. However, future growth builds from today's much larger base, meaning that tomorrow's energy requirements are unprecedented in scale. This will pressure the global supply system and require increased emphasis on energy-use efficiency in transportation, residential, commercial, and industrial sectors.

This chapter examines how credible, integrated modeling efforts portray the future world energy situation, and identifies the implications of these projections. Subgroups examined a wide range of demand data from public and aggregated proprietary sources, making no attempt to produce a new consensus projection. Expert teams assessed technologies that hold potential for critical efficiency gains; coal demand and supply trends; and how cultural, social, and economic conditions and other non-technical forces shape energy demand.

The outline of the Energy Demand chapter is as follows:

- Demand Study Observations
- Demand Summary
- Demand Data Evaluation
- Electric Generation Efficiency
- Coal Impact
- Industrial Efficiency
- Cultural/Social/Economic Trends
- Residential/Commercial Efficiency
- Demand Study Potential Policy Options
- Policy Recommendations.

The Demand Task Group organized its activities into six subgroups (Demand Data Evaluation, Electric Generation Efficiency, Coal Impact, Industrial Efficiency, Cultural/Social/Economic Trends, and Residential/Commercial Efficiency). The output of these efforts led to a series of observations and development of potential policy options. Detailed discussions of the work of each subgroup have been included in the report as topic papers. These topic papers are included on the CD distributed with the report (a list of all the topic papers can be found in Appendix E).

- The purpose of the Demand Data Evaluation subgroup was to summarize and compare the output from publicly available, integrated energy projections for the world, to understand the underlying basis of those projections, and to compare the results with other projections that were either non-integrated or available only as aggregated proprietary studies.
- The intent of the Electric Generation Efficiency subgroup was to understand the efficiency potential in the electric generation sector and estimate

the portion of that potential that is included in the available projections.

- The Coal Impact subgroup examined both the coal supply and demand trends. The primary goals were to compare the projected demand for coal in the outlooks examined with the potential future supply of coal on a worldwide and regional basis and to evaluate coal transportation factors.
- The focus of the Industrial Efficiency subgroup was to define the potential for energy-efficiency improvement in the industrial energy sector and to compare that potential to an estimate of the efficiency that is embedded in the outlooks examined for the study. This effort also investigated historical patterns of industrial feedstock use and how they changed over time.
- The Cultural/Social/Economic Trends subgroup undertook a broad area of investigation aimed at examining how non-technical factors affect energy demand, including how these factors have changed over time and how they might be expected to change in the future.
- The Residential/Commercial Efficiency subgroup looked at the potential for energy-efficiency improvement in the residential and commercial end-use sectors. Much of this effort focused on the potential to reduce energy losses in existing structures, the potential impact of appliance standards on energy use, and the potential impact of new building standards.
- Each of these subgroup efforts resulted in formation of observations associated with the respective areas. The Demand Task Group reviewed all of the observations and organized them into a list of those that appear to be the most significant.
- The next step in the process was to develop potential policy options, which were used as input into the study recommendations process after the Demand Task Group reduced the overall list to those it identified as most significant.

DEMAND STUDY OBSERVATIONS

The output of each of the demand subgroups provides a broad view of historical and projected worldwide and regional energy use. Many observations were derived from the subgroups' efforts. The list of observations were reduced to eighteen that the Demand Task Group deemed to be the most significant and broad based.[1] The rest of the observations can be found in the individual demand subgroup reports located in the topic papers.

1. **Income and population are prime drivers of energy demand.**

   The assumed rate of economic growth is a key variable in projections of global energy demand. Population growth and the size of a region's population are also important variables. Projected annual average global economic growth from 2000 to 2030 ranges from 3 percent to 4.4 percent in the publicly available integrated energy outlooks. From 1980 to 2000, global economic growth averaged 3.1 percent.

2. **There are varying views on the rate of global energy demand growth.**

   Projected annual average global energy demand growth from 2000 to 2030 ranges from 1.5 percent to 2.5 percent. Global energy demand growth averaged 1.7 percent from 1980 to 2000. High and low projections of economic growth result in high and low projections, respectively, of future energy growth. The difference in energy demand in 2030 between the high and low growth rates is 224 quadrillion Btu—equivalent to roughly half of global demand in 2005.

3. **There is a range of views on the rate of U.S. economic and energy demand growth.**

   Projections of annual average U.S. economic growth from 2000 to 2030 in the public energy outlooks range from 2.3 percent to 3.3 percent. The 1980 to 2000 average was 3.2 percent. Projected annual average U.S. energy demand growth ranges from 0.5 percent to 1.3 percent. The 1980 to 2000 average was 1.2 percent. The difference between the high and low energy demand growth rates from 2000 to 2030 is 37 quadrillion Btu—equivalent to 37 percent of 2005 total U.S. energy demand.

4. **In most cases, carbon dioxide emissions are closely related to projected energy use.**

   Projected global carbon dioxide emissions generally grow at roughly the same rate as projected energy demand, while growth in the United States is slightly slower than energy demand growth.

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[1] Unless otherwise noted, data referred to in this chapter and used in its figures and tables are from the Energy Information Administration's (EIA) *International Energy Outlook 2006* and the International Energy Agency's (IEA) *World Energy Outlook 2006*. These data were gathered by the NPC Survey of Global Energy Supply/Demand Outlooks.

5. **Fossil fuels remain the largest source of energy.**

   In 2030, fossils fuels (oil, natural gas, and coal) are projected to account for between 83 and 87 percent of total world energy demand compared with 85 percent in 2000. The share for the United States ranges from 81 to 87 percent in 2030. The U.S. share in 2000 was 86 percent.

6. **The projections indicate that a large and, in many cases, growing share of energy use will be met by coal.**

   In all of the projections but one, annual average demand growth for coal is faster than in the past for both the United States and the world. Resources do not appear to be limiting the projected growth in coal use. However, use of coal will require infrastructure development, especially for transportation and unconventional uses such as coal to liquids.

7. **In most of the outlooks, world natural gas demand is projected to increase at a slower rate than in the past (1980 to 2000).**

   Natural gas demand growth is still faster than total energy demand from 2000 to 2030. The result is natural gas gaining in market share.

8. **Growth in U.S. natural gas demand is projected to be significantly slower than in the past (1980 to 2000), which results in a decline in its share of total U.S. energy.**

   Despite slower demand growth, absolute U.S. consumption of natural gas is projected to continue to grow.

9. **Projected world demand growth for oil is faster than in the past (1980-2000), but less than the projected overall increase in energy demand resulting in a declining market share for oil.**

   Annual average growth in world oil demand between 2000 and 2030 is projected to increase at an annual average rate ranging from 1.0 to 1.9 percent. From 1980 to 2000, annual growth in world oil demand averaged 0.9 percent. In most cases, U.S. oil demand growth equals or exceeds the 0.6 percent annual average growth rate from 1980 to 2000.

10. **Nuclear energy use is projected to contribute a declining share to world energy and U.S. energy consumption, but it grows in absolute terms.**

    Both world and U.S. projections show nuclear energy use growing slower than total energy demand, and losing its share of the energy mix.

11. **Transportation oil use is the largest component of oil demand growth in the world and the United States.**

    Transportation increases its share of world and U.S. oil use.

12. **The share of natural gas use in the major end-use sectors—residential/commercial, industrial, and electric generation—changes over time.**

    The publicly available projections show a declining share of world natural gas use in the residential and commercial sectors, essentially a constant share for industrial purposes, and an increasing share for electric generation. In the United States, the natural gas share remains essentially constant in the residential/commercial sector, while it declines in the industrial sector and grows for electric generation.

13. **Energy demand in Asia/Oceania is projected to grow at a faster rate than the global and U.S. averages.**

    Projected energy growth in the publicly available integrated projections indicates that Asia/Oceania's share of total world energy demand will increase by about 10 percent between 2000 and 2030. Over the same period, despite rising absolute consumption, the United States' share of total world energy use is projected to decline by about 2 percent.

14. **Energy use is projected to grow slower than economic activity in both the world and the United States, resulting in a projected decline in energy intensity.**

    World energy use is projected to grow slower than economic growth. This is a continuation of past trends. The United States is expected to exhibit a similar profile. Energy intensity (energy use per unit of gross domestic product, GDP) declines at a faster rate in Asia/Oceania than in North America.

15. **Global and U.S. energy consumption, per capita, is projected to increase.**

    With the exception of one case, in all the publicly available integrated projections, energy use per capita increases in the world, Asia, and the United States. From 1980 to 2000, energy use per capita was essentially constant in the United States, while it increased in Asia.

16. **U.S. per capita energy consumption is projected to remain higher than the world average.**

    In most publicly available projections, U.S. energy use per capita in 2030 is projected to be 4 times greater than the world average and 6 times greater than in Asia. In 2000, the U.S. to world ratio was 5 and U.S. to Asia ratio was 11.

17. **U.S. energy efficiency improvement, as measured by energy intensity, is projected to be equal to—or less than—the historical rate from 1980 to 2000.**

    Data limitations constrain insights into the amount of efficiency increase outside the United States that is built into the projections. However, the decrease in energy intensity suggests that there is an increase in energy efficiency underpinning many of the projections. U.S. new light duty vehicle miles per gallon (mpg) appears to be projected to increase at 0.6 percent per year. U.S. industrial efficiency is estimated to increase by 5 percent over the projection period. There is potential for further energy efficiency improvement in both of these sectors as well as in the residential/commercial sectors.

18. **Applying additional policy initiatives could change the energy, economic, and environmental outlook.**

    In a projection that assumed the enactment of several additional policies—the IEA Alternative Policy Case—total world energy demand growth from 2000 to 2030 was about 0.4 percent per year lower then in the IEA Reference Case. In the same Alternative Policy Case, growth in U.S. energy demand was 0.3 percent per year lower than in the Reference Case. Global carbon dioxide emissions are 6 billion metric tons lower (34 billion metric tons) in 2030 in the IEA Alternative Policy Case than in the IEA Reference Case (40 billion metric tons).

DEMAND SUMMARY

The NPC Demand Task Group reviewed, analyzed, and compared projections of world energy demand. These projection data were gathered by the NPC Survey of Global Energy Supply/Demand Outlooks and collected in the NPC data warehouse, a repository for data and information used in this study, which is discussed in the Methodology chapter. Publicly available demand data from the U.S. Department of Energy's Energy Information Administration and the International Energy Agency were the main focus of the analysis. Aggregated proprietary data and data from other, generally less complete, public outlooks were used primarily to establish whether the EIA and IEA outlooks provided a reasonable range of projections for analysis.

The three major input assumptions behind both the EIA and the IEA projections are economic growth, population, and energy policies. In general, the economic growth projections (2000 to 2030) for the world exceed past (1980 to 2000) growth. World population growth projections in all cases are essentially the same. Population growth rates are projected to be generally lower than historical growth rates.

The EIA projections generally include only those energy policies that are currently in effect and allow most policies to expire as currently enacted at their sunset dates. The IEA Reference Case, however, assumes the likely extension of public policies. The IEA Alternative Policy Case provides a significantly different energy policy approach, assuming not only existing energy policies and their logical extension, but also other policies that are under consideration around the world. Projected worldwide energy demand is shown in Figure 1-1, while projected U.S. energy demand is shown in Figure 1-2.

World demand for petroleum liquids is projected to grow from about 76 million barrels per day in 2000 to between 98 and 138 million barrels per day in 2030 (Figure 1-3). U.S. petroleum liquids demand is projected to grow from about 19 million barrels per day in 2000 to between 21 and 30 million barrels per day in 2030 (Figure 1-4).

World natural gas demand is projected to range from 356 to 581 billion cubic feet per day in 2030, compared with 243 billion cubic feet per day in 2000 (Figure 1-5). U.S. natural gas demand, which was 64 billion cubic feet per day in 2000, is projected to

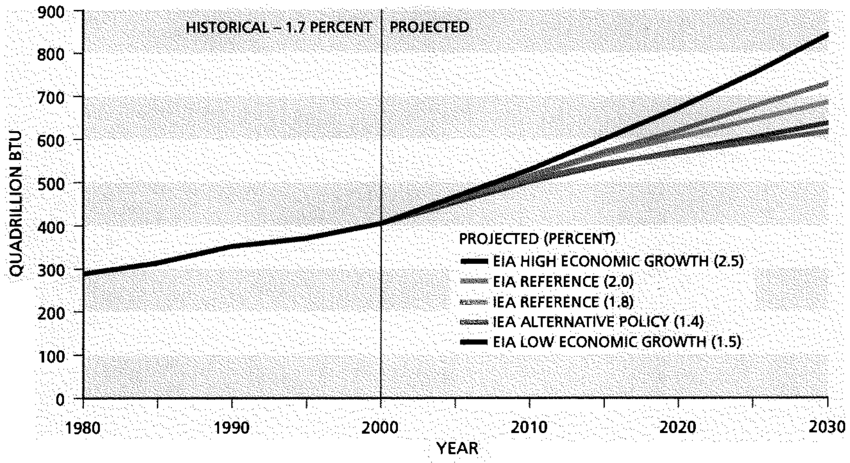

FIGURE 1-1. *World Energy Demand — Average Annual Growth Rates*

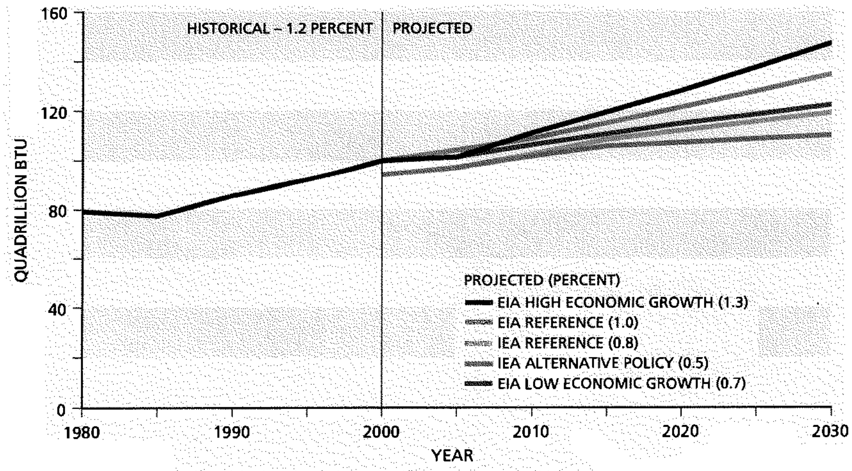

FIGURE 1-2. *U.S. Energy Demand — Average Annual Growth Rates*

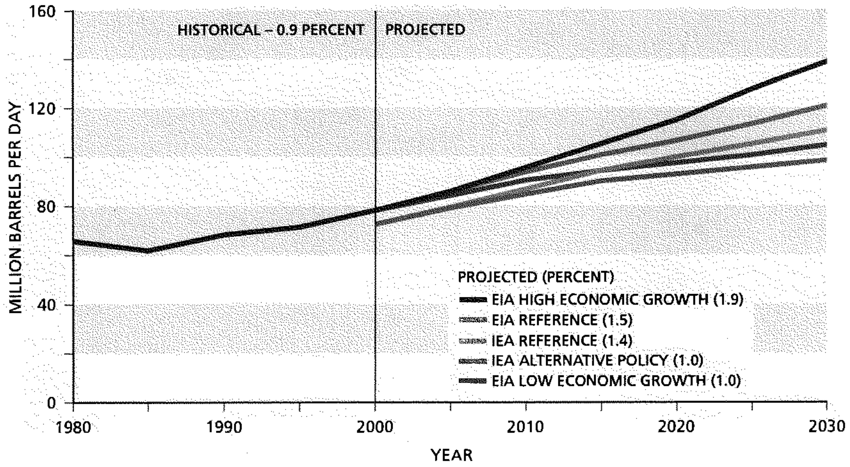

FIGURE 1-3. *World Petroleum Demand — Average Annual Growth Rates*

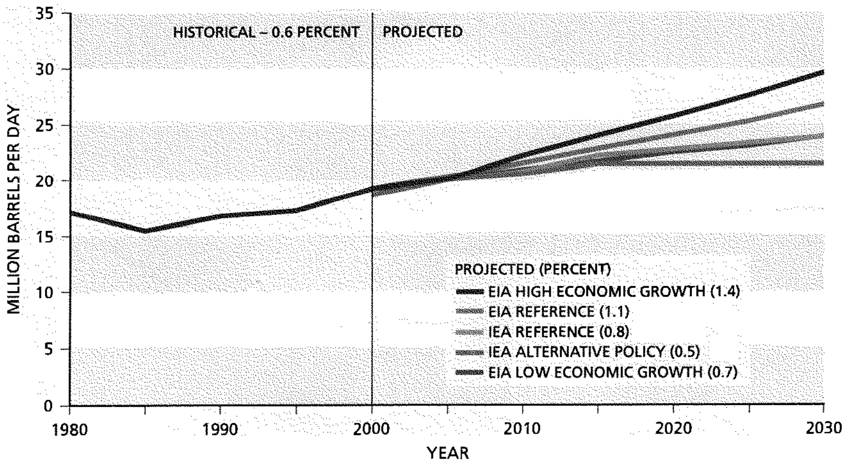

FIGURE 1-4. *U.S. Petroleum Demand — Average Annual Growth Rates*

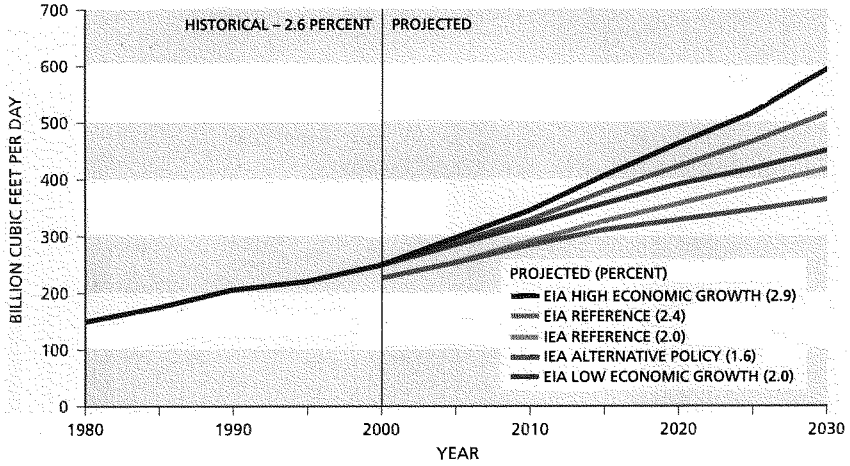

FIGURE 1-5. *World Natural Gas Demand — Average Annual Growth Rates*

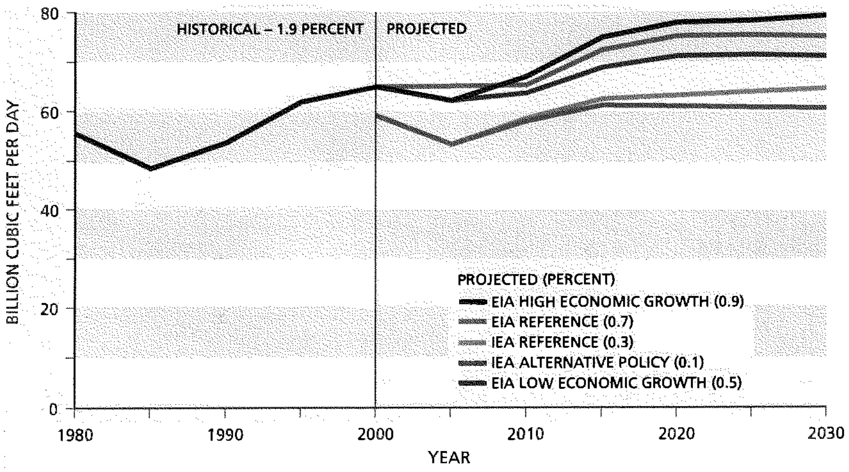

FIGURE 1-6. *U.S. Natural Gas Demand — Average Annual Growth Rates*

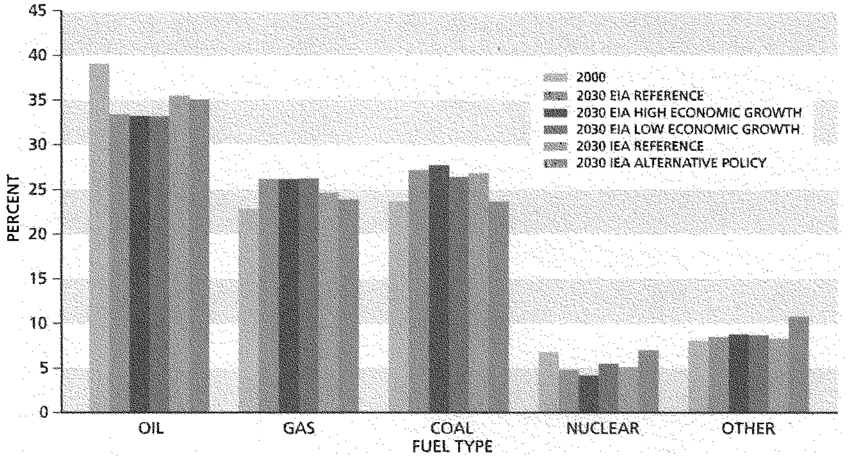

FIGURE 1-7. *World Energy Supply Shares*

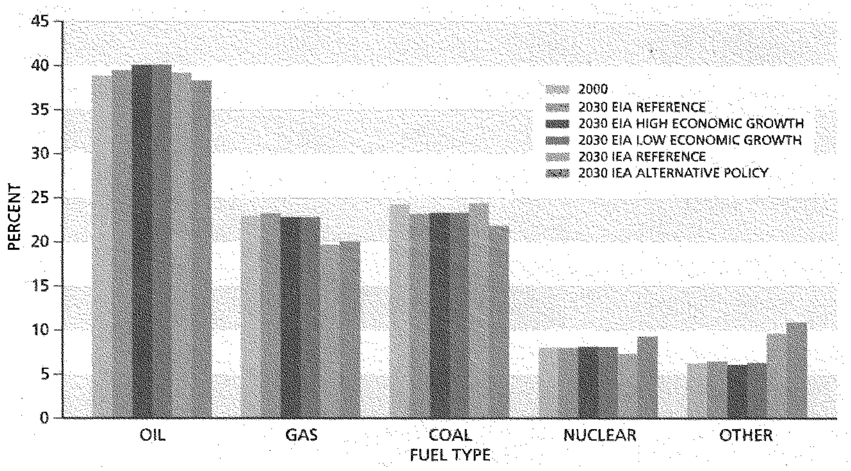

FIGURE 1-8. *U.S. Energy Supply Shares*

range from 59 to 78 billion cubic feet per day in 2030 (Figure 1-6).

On a world basis, oil use is generally expected to lose share, while share gain is expected in the United States. On the other hand, worldwide natural gas use share is projected to increase (Figure 1-7). In the United States, the projections indicate little change to a slight decline in natural gas use share (Figure 1-8).

Worldwide carbon dioxide emissions grow from 24 billion metric tons in 2000 and are projected to range from 34 to 51 billion metric tons in 2030 (Figure 1-9). In all cases, carbon dioxide emissions increase at about the same rate as energy demand. In 2030, projected carbon dioxide emissions in the United States range from 6.3 to 9 billion metric tons compared with 5.8 billion metric tons in 2000.

Regional shares of energy use are projected to change over time. The share of total worldwide energy consumed in North America, OECD Europe, and Non-OECD Europe & Eurasia is projected to fall in all of the cases, while the share in Asia/Oceania grows (Table 1-1). In general, the change in the oil share of total worldwide oil consumed by region parallels the change in the share of total energy consumption, with industrialized regions losing share and the Asia/Oceania oil share increasing significantly.

	2000 IEA	2030 IEA Ref. Case
North America	27%	21%
Central and South America	5%	5%
OECD Europe	18%	13%
Non-OECD Europe & Eurasia	10%	8%
Middle East	4%	6%
Asia/Oceania	31%	41%
Africa	5%	6%

TABLE 1-1. Regional Energy Shares

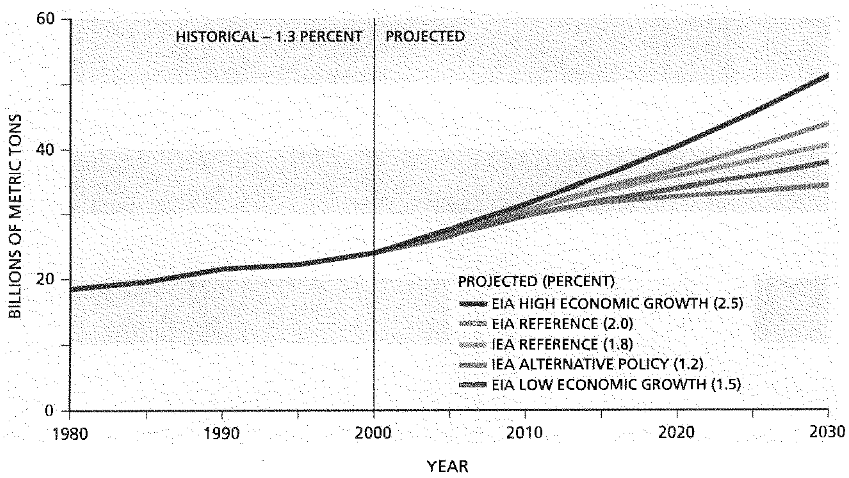

FIGURE 1-9. *World Carbon Dioxide Emissions — Average Annual Growth Rates*

Improvement in the efficiency of energy use is an important factor determining future energy use. The models used to project future energy use are complex, which makes it difficult to provide precise estimates of the efficiency improvement built into the projections. However, energy use intensity (energy use per unit of GDP) provides a useful proxy and is projected to decline in all regions.

Major Areas to Moderate Demand by Increasing Energy Efficiency

Vehicle Fuel Economy

The major use of liquid fuels in the United States is for transportation. The projections that were studied indicate that transportation will likely remain the primary use of liquid fuels in the United States. Among various transportation uses, light duty vehicle use (automobiles and light trucks) is the largest component. Significant potential exists for efficiency improvements, but most projections do not expect this potential to be fully realized. In most of the other transportation uses, the EIA Reference Case projection uses most or all of the potential for efficiency improvement now or expected to be available.

Technically, there appears to be a potential for improving the efficiency of new light duty vehicles (fuel used per unit travel) by about 50 percent using technology improvements in several areas: engine efficiency; body improvements; driveline changes; accessory modifications; and hybrid technology use. Some of the changes are likely to have costs associated with them as well as possible broader economic effects (see Technology chapter).

The NPC global oil and gas study has not been conducted in a way that provides for internally generated projections. However, it is possible to understand the potential size of an impact on U.S. light duty fuel consumption from incorporating an efficiency improvement of 50 percent in the U.S. new vehicle sales mix by 2030. By removing assumptions that relate to changes in the vehicle sales mix, increases in vehicle performance, increases in vehicle energy use created by added comfort and convenience options, and increases in miles driven per licensed driver, most of the factors that complicate direct understanding of a single factor like vehicle efficiency increase are set aside.

The 50 percent improvement in new vehicle efficiency that has been discussed thus far is not consistent with the general public understanding of light duty vehicle efficiency. The general measure used to indicate the fuel-use characteristic of a vehicle is miles traveled per gallon of fuel used (mpg). A 50 percent reduction in fuel used per mile of travel (efficiency) is, mathematically, equivalent to a doubling of—or a 100 percent increase in—mpg.

There are many ways to build a fuel use estimate of the impact of incorporating a new light duty vehicle efficiency improvement. Consequently, any estimate is, at best, an indication of magnitude and not a projected actual outcome. If it is assumed that the total 100 percent improvement in new vehicle fuel economy is implemented by the year 2030, the potential impact appears to lower light duty vehicle fuel consumption by 3 to 5 million barrels per day relative to a future with no improvement in new vehicle fuel economy. Factors such as rate of new vehicle technology penetration and new vehicle replacement in the on-road fleet have impacts on reduction in fuel use. New vehicle fuel economy improvement might vary from the rapid improvement rate in new vehicle fuel economy that occurred when the Corporate Average Fuel Economy program was instituted in the 1970s to a gradual incorporation of new vehicle efficiency over the period to 2030. Replacement of on-road light duty vehicles by new light duty vehicles has taken about 15 years. If the replacement period for light duty vehicles in the on-road fleet increases or decreases, the potential fuel use reduction decreases or increases.

Obviously there are many other factors that are likely to change with time. Consequently, the estimate of potential savings should not be applied to any specific future projection of U.S. light duty fuel demand, but should be used to indicate potential magnitude. The ultimate outcome will depend on the specifics of program design and implementation.

Consumption in the Residential and Commercial Sectors

There appears to be sizeable potential to reduce energy consumption in U.S. residential and commercial sectors. The EIA *Annual Energy Outlook 2007* (AEO 2007) reported the residential/commercial efficiency factors that are included in the projection. The factors shown in Table 1-2 are greatly influenced by the replacement of old, relatively inefficient

Category	Appliance	Efficiency Improvement
Appliance	Refrigerators	22%
	Freezers	8%
Space heating	Electric heat pumps	16%
	Natural gas heat pumps	14%
	Geothermal heat pumps	5%
	Natural gas furnaces	6%
	Distillate furnaces	2%
Space cooling	Electric heat pumps	20%
	Natural gas heat pumps	10%
	Geothermal heat pumps	6%
	Central air conditioners	22%
	Room air conditioners	7%
Water heaters	Electric	3%
	Natural gas	6%
	Distillate fuel oil	0%
	Liquefied petroleum gases	0%
Building shell efficiency	Space heating – Pre 1998 homes	7%
Note: Index includes size of structure in the calculation	Space cooling – Pre 1998 homes	2%
	Space heating – New construction	2%
	Space cooling – New construction	2%

Source: Energy Information Administration, *Annual Energy Outlook 2007,* table 21, http://www.eia.doe.gov/oiaf/aeo/supplement/sup_rci.xls.

TABLE 1-2. *Residential Stock Efficiency Improvements, 2007-2030*

equipment. Efficiency improvement in new equipment is expected to be less than the aggregated improvements in the table.

Studies for efficiency improvements are largely specific to regions, and often to energy types. A review of these studies suggests that anticipated energy use in the residential and commercial sectors could be reduced by roughly 15 to 20 percent through deployment of cost-effective energy-efficiency measures that use existing, commercially available technologies. Assuming that all these measures are put in place over the next decades and that all other factors such as level of services are held constant, U.S. residential/commercial energy consumption could be reduced by 7 to 9 quadrillion Btu. Technologies to accomplish savings of these magnitudes are indicated to be available in the marketplace. However, some of these measures have initial cost and retrofit issues associated with their use.

While significant efficiency improvements have been made over the last several decades in building shells, systems, and appliances, these have been offset in part by additional energy service demand requirements that have been imposed as a result of increased structure sizes and larger and multiple appliance use. As much as possible, programs to increase the efficiency in the U.S. residential/commercial sector need to avoid inclusion of measures that inadvertently encourage using energy services that decrease the effectiveness of energy-efficiency measures.

U.S. Industrial Sector Efficiency

The industrial sector is a price-responsive consumer of energy. U.S. energy-intensive industries and manufacturers rely on internationally competitive energy supplies to remain globally competitive. In recent years, U.S. natural gas prices have risen relative to those in the rest of the world. As a result, U.S. energy-intensive industries and manufacturers using natural gas as a fuel or feedstock have responded by increasing the efficiency of their operations and/or by shifting a greater proportion of their operations outside the United States.

Energy efficiency opportunities exist for reducing energy use by about 15 percent broadly across the industrial sector. Areas of opportunity include waste heat recovery, separations, and combined heat and power. While 40 percent of that opportunity could be implemented now, research, development, demonstration, and deployment are required before the rest can be implemented. If all of this efficiency could be put in place over the next 20 years, U.S. energy demand could be reduced by 4 to 7 quadrillion Btu compared with what it would be without the improvements.

Table 1-3 indicates some of the barriers to adopting industrial energy efficiency measures.

Research, development, and demonstration are needed to prove the technologies. However, focus on deployment of improved technologies and practices is particularly important because of the risk-averse character of manufacturing companies, the high capital cost of new equipment, the long life cycle of existing industrial equipment, access to unbiased information on technology performance, and lack of technically trained human resources. Addressing these issues will speed the diffusion of improved technologies and practices.

Making the federal research and development tax credit permanent, instead of legislatively renewing it every few years, is a way to encourage private investment in industrial energy-efficiency research, development, demonstration, and deployment.

U.S. Electric Power Generation Efficiency

U.S. electricity generation efficiencies indicated in both the EIA and IEA outlooks show improvements over time. The expected improvements come mainly

Energy Cost Environment	• Price volatility • Lack of transparency to end-users of the real cost of energy
Business Environment	• Technical and economic risk (uncertain return on investment) associated with efficiency projects • Initial capital costs influence decisions more than long-term energy costs • Lack of incentives for development and use of new technology • Lack of R&D investments in efficiency • Long service life of existing equipment
Regulatory Environment	• Election cycles and impact on R&D priorities • Uncertainty related to future regulation, particularly environmental, and power • Permitting hurdles for upgrading existing equipment
Education Environment	• Inadequate industry awareness of new technology • Lack of technical expertise

Sources: Energetics, Technology Roadmap: Energy Loss Reduction and Recovery in Industrial Energy Systems, 2004; Global Environmental Facility (GEF), Operation Program Number 5: Removal of Barriers to Energy Efficiency and Energy Conservation, 2003; Marilyn Brown, Market Failures and Barriers as a Basis for Clean Energy Policies, 2001; A.B. Jaffe, R.G. Newell, R.N. Stavins, "Energy-Efficient Technologies and Climate Change Policies: Issues and Evidence," Resources for the Future, Climate Issue Brief No. 19, 1999.

TABLE 1-3. *Barriers to Adopting Energy Efficiency Measures*

from the replacement of retired plants with new plants that have better efficiencies. However, installation of environmental control systems will add internal energy requirements reducing the efficiency of a power generation plant.

There are a few changes that can be made to make an existing power generation plant more efficient. Studies suggest the potential to improve the efficiency of existing U.S. power plants by 2 to 6 percent. Existing electric generation plant efficiency improvements generally fall into the following categories.

- Improved operation and maintenance practices
- Replacement/upgrade of:
  - steam turbines
  - forced draft, primary air, and induced draft fans
  - condensers
  - air heaters
  - operating controls
  - soot blowers
  - burners.

If these efficiency improvements could be captured in the next decades, energy savings would equal about 1 quadrillion Btu.

Capturing Efficiency Potential

Current energy-efficiency polices will place downward pressure on future U.S. energy consumption. However, further energy reduction would be possible if additional energy-conservation-related policy is put in place.

In commercially oriented end-uses such as industrial, electric generation, and commercially oriented transportation, the market price mechanism creates an incentive for using economically available energy efficiency technology. Programs to assist in research, development, demonstration, and deployment of energy-efficient technology would bolster the market mechanism in these areas.

Energy conservation and efficiency use in areas where individual consumers are faced with complex choices that are not well understood, and where decisions are made by third parties who are not consuming and paying for the energy, are likely to benefit from prudent application of technically practical and economically rational policies. Areas such as light duty vehicle fuel use and residential and commercial energy use could potentially benefit from well developed and implemented energy conservation/efficiency policies.

DEMAND DATA EVALUATION ✦

The Demand Data Evaluation Subgroup of the Demand Task Group reviewed, analyzed, and compared projection data collected in the NPC data warehouse, which is discussed in the Methodology chapter. Publicly available demand data from EIA and IEA were the main focus of the analysis. The aggregated proprietary data available in the NPC data warehouse were used primarily to establish whether the EIA and IEA projections provided a reasonable range of projection results. Other public projections, generally less complete than the EIA and IEA projections, were also used as a reasonableness check.

The three major input assumptions behind both the EIA and the IEA projections are economic growth, population, and effect of associated energy policies. In general, the economic growth projections (2000 to 2030) for the world exceed past (1980 to 2000) growth except for that used in the EIA Low Economic Growth Case (Figure 1-10). By region and country, the pattern is somewhat different. Economically developed regions (North America and OECD Europe), and both developing and economically emerging Asia are projected to grow more slowly than in the past. Countries in Africa, Central and South America, the Middle East, and Non-OECD Europe and Eurasia are projected to grow more rapidly than historically. The faster global economic growth is driven by the rapidly growing emerging Asian economies becoming a larger share of the global economy.

World population growth in all cases is essentially the same, drawn from United Nations or U.S. Census projections of population growth. Population growth rates are projected to be generally lower then historical growth rates.

The EIA, generally, only included those energy policies that are currently in effect and allows most policies to expire at their currently enacted sunset date. The IEA Reference Case, however, assumes the likely extension of public policies. The IEA Alternative

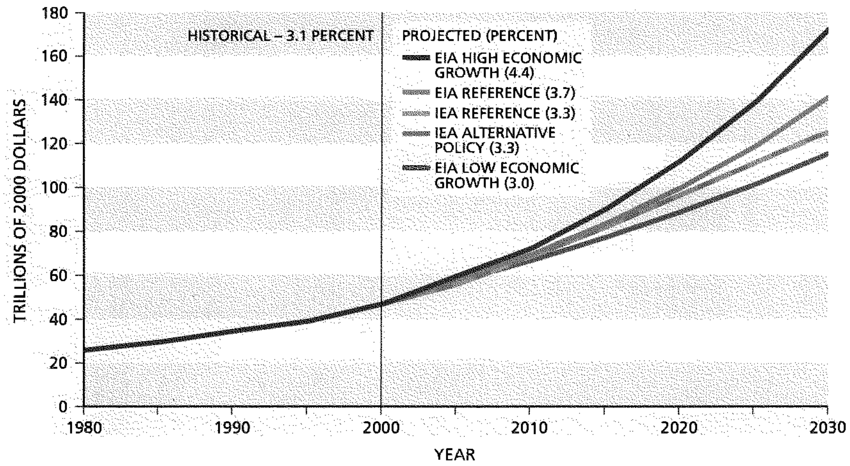

FIGURE 1-10. *World Economy—Average Annual Growth Rates*

Policy Case provides a significantly different energy policy approach, assuming not only existing energy policies and their logical extension, but also other policies now under consideration around the world. IEA used the same economic projections in its Reference Case and Alternative Policy Case.

Worldwide energy demand is projected to grow 1.4 to 2.5 percent per year, versus the historical growth rate of 1.7 percent per year (Figure 1-11). The projected U.S. energy demand growth of 0.5 to 1.3 percent per year was generally less than the historical rate of growth of 1.2 percent per year (Figure 1-12).

World demand for petroleum liquids is projected to grow at 1.0 to 1.9 percent per year versus the historical growth rate of 0.9 percent per year. In 2030, petroleum demand is projected to range from 98 to 138 million barrels per day, up from 76 million barrels per day in 2000 (Figure 1-13). Despite this growth, petroleum as a share of total energy declines in all cases. U.S. petroleum demand is projected to grow 0.5 to 1.4 percent per year versus 0.6 percent per year historically. In 2030, U.S. petroleum liquids demand is projected to range from 21 to 30 million barrels per day, compared to 19 million barrels per day in 2000 (Figure 1-14). The IEA Alternative Policy Case is the only public case in which growth in U.S. petroleum liquids demand is slower than in the past. This indicates that the policies assumed in this case could have a significant impact on the growth in petroleum liquids demand relative to the policies in place today.

According to the EIA projection for the United States, two-thirds of the volume and most of the projected growth in demand for petroleum liquids is in transportation services (Figure 1-15). That projected growth in transportation is led by increased demand by light duty vehicles (60 percent) (Figure 1-16). The key drivers of light duty vehicle growth are increased vehicle penetration and annual miles traveled per vehicle, which more than offset improvement in vehicle efficiency (miles per gallon).

The transportation sector provides the greatest potential for reducing oil consumption. The Technology Task Group, through its Transportation Efficiency subgroup, developed an estimate of transportation efficiency potential for five classes of transportation: light duty vehicles, heavy duty vehicles, air, marine, and rail (see Technology chapter).

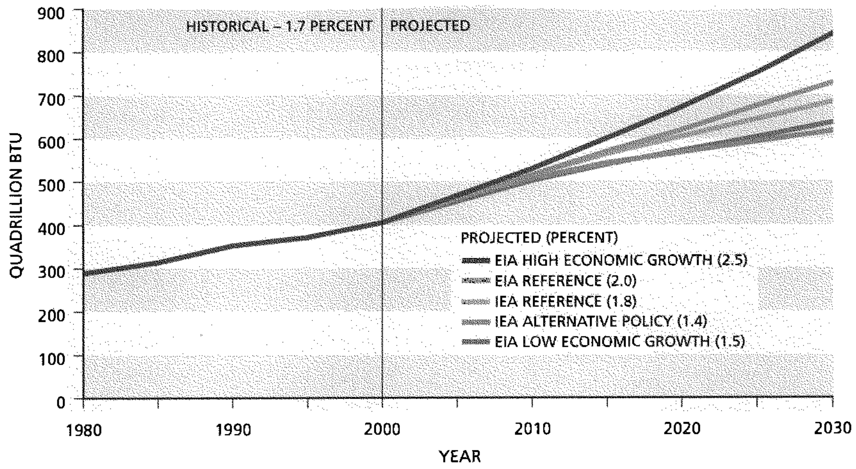

FIGURE 1-11. *World Energy Demand — Average Annual Growth Rates*

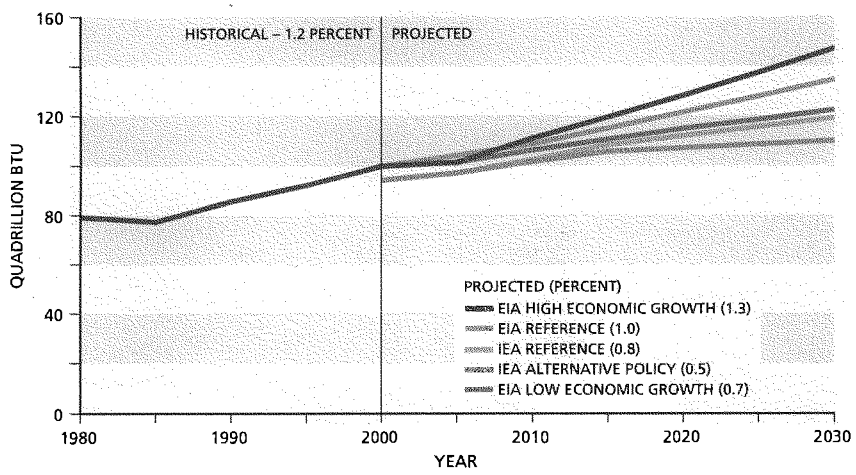

FIGURE 1-12. *U.S. Energy Demand — Average Annual Growth Rates*

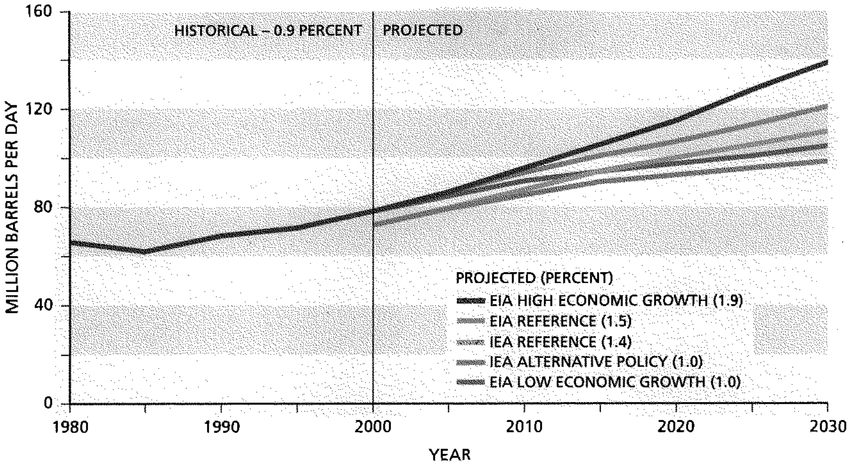

FIGURE 1-13. *World Petroleum Demand — Average Annual Growth Rates*

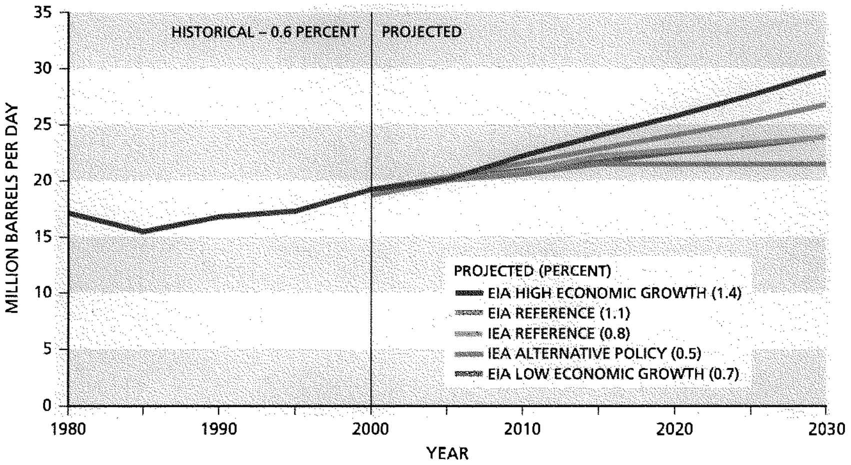

FIGURE 1-14. *U.S. Petroleum Demand — Average Annual Growth Rates*

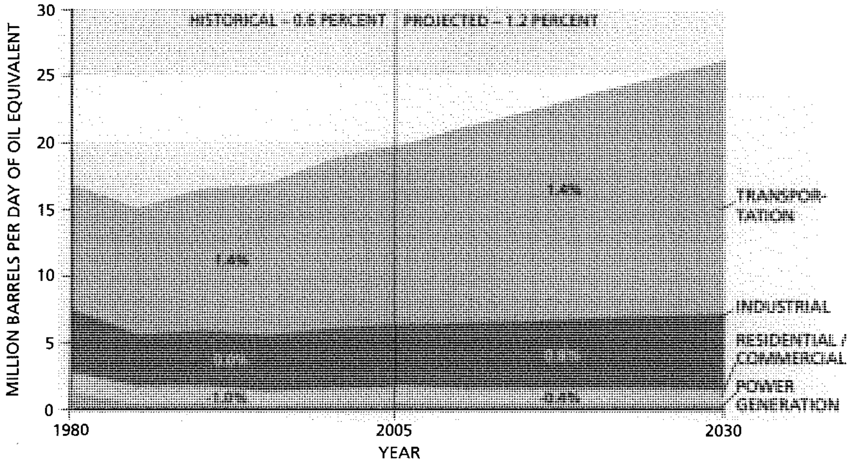

FIGURE 1-15. *U.S. Demand for Petroleum Liquids by Sector (EIA Reference Case) — Average Annual Growth Rates*

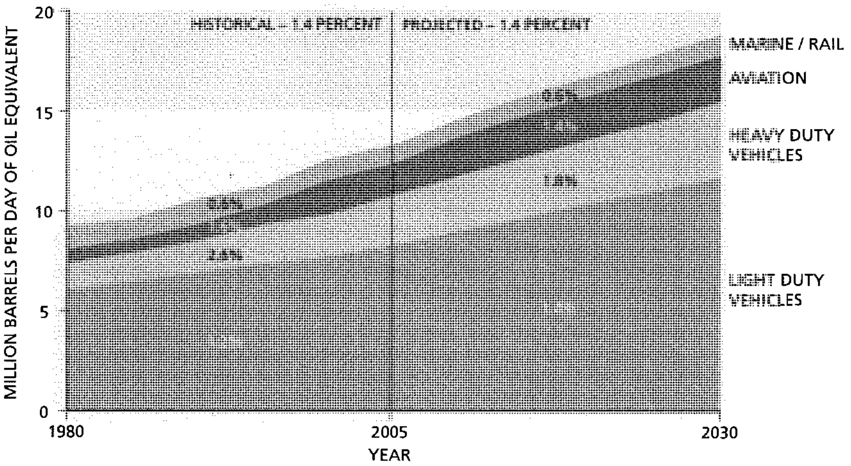

FIGURE 1-16. *U.S. Demand for Transportation Fuels by Transportation Mode (EIA Reference Case) — Average Annual Growth Rates*

The EIA Reference Case for the United States projects that in 2030 technology improvements will result in ~10 percent improvement in new light duty vehicle fuel consumption (Btu per mile) from 2005 levels. It is estimated that this includes technological improvements of ~30 percent at constant vehicle performance, and vehicle attribute changes that reduce this improvement by about half. Based on this study's analysis, technologies (drive-train and body improvements, and hybridization) exist, or are expected to be developed, that have the potential to reduce fuel consumption by 50 percent relative to 2005. This assumes constant vehicle performance, characteristics, and sales mix between light trucks and autos and entails higher vehicle cost.

Improvements beyond 50 percent will require breakthroughs in batteries or fuel cells, resulting in significantly higher vehicle costs and potentially significant infrastructure investments. The fuel efficiency improvement estimates beyond the initial 50 percent warrant careful scrutiny as other energy forms such as electricity and hydrogen are incorporated in the fuel mix. The conversion and transformation of primary fuels to secondary energy types may significantly decrease the overall energy efficiency of these advanced technologies.

Technologies exist to reduce new heavy-duty-truck fuel consumption by 15-20 percent in the United States by 2030, which is about equal to the EIA Reference Case assumption. These technologies (e.g., engine efficiency, rolling resistance, and aerodynamic improvements) will involve higher cost and require appropriate incentives. Operational improvements such as reduced idling and improved logistics can provide a benefit of 5 to 10 percent across the fleet during this period.

Advanced technology solutions, such as hybridization and fuel cells, offer fuel consumption reductions of an additional 25 percent, and applications would likely be initiated in local delivery, short-haul, medium-duty delivery trucks, and buses. As in the light duty vehicles, the conversion and transformation of primary fuels to secondary energy types may significantly decrease the overall energy efficiency of these advanced technologies.

Fuel consumption improvements for aircraft on the order of 25 percent are the basis for the EIA Reference Case. This is an aggressive projection and all of the known technologies appear to be included in the EIA estimates. New technologies will need to be discovered to achieve additional improvements in efficiency.

The EIA Reference Case is based on a 5 percent improvement in marine shipping fuel consumption by 2030. This improvement level is achievable with operational solutions and existing technologies. Improvements greater than 5 percent will require new hull designs and new propeller designs. Given the long life of ships (greater than 20 years), migration of these solutions into the fleet will not have a large impact until later in the study period. Operational changes, affecting the entire fleet, may be more significant sooner than technological improvements.

The EIA Reference Case assumes that fuel consumption will improve by 2.5 percent between 2005 and 2030 for rail use in the United States. Incremental improvements in engine design, aerodynamics, and use of hybrids have the potential to reduce new locomotive fuel consumption by up to 30 percent over 2005 technology. Rollout of new technology into the fleet is slow due to low turnover and will be difficult to achieve during the years considered in this study. More stringent emissions standards will tend to increase fuel consumption.

World natural gas demand is projected to grow 1.6 to 2.9 percent per year versus 2.6 percent per year historically (Figure 1-17). Despite the slowing of gas demand growth rates, gas is still projected to gain market share versus other energy sources in all cases. Natural gas demand grows in all regions. Gas demand ranges from 356 to 581 billion cubic feet per day in 2030, compared with world natural gas demand of 243 billion cubic feet per day in 2000. In all cases, the projected growth rate in U.S. natural gas demand is lower than the historical rate. U.S. natural gas demand ranges from 59 to 78 billion cubic feet per day in 2030, compared with 64 billion cubic feet per day in 2000 (Figure 1-18).

In contrast with projected U.S. oil demand, which is concentrated in the transportation sector (Figure 1-15), natural gas use in the United States is more evenly spread across three sectors: residential/commercial, industrial, and electric utility (Figure 1-19).

Worldwide, coal demand growth is projected to be faster in the future than in the past in all outlooks except for the Alternative Policy Case where the growth is slightly less than in the past. More than two-thirds

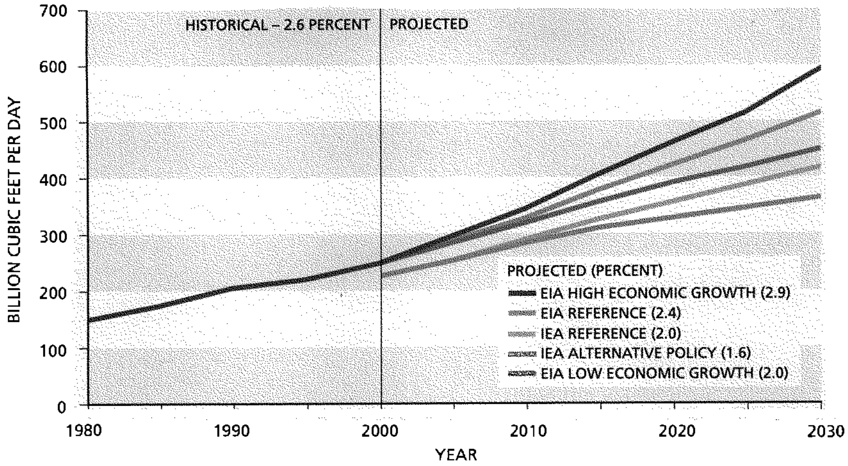

FIGURE 1-17. *World Natural Gas Demand — Average Annual Growth Rates*

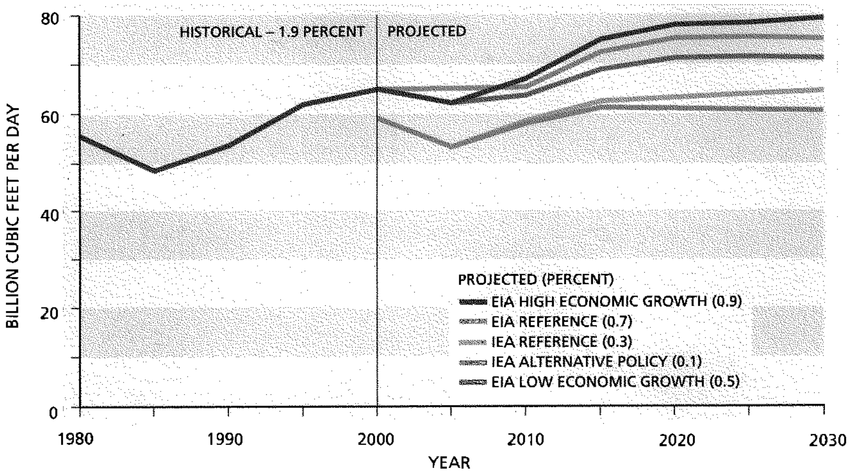

FIGURE 1-18. *U.S. Natural Gas Demand — Average Annual Growth Rates*

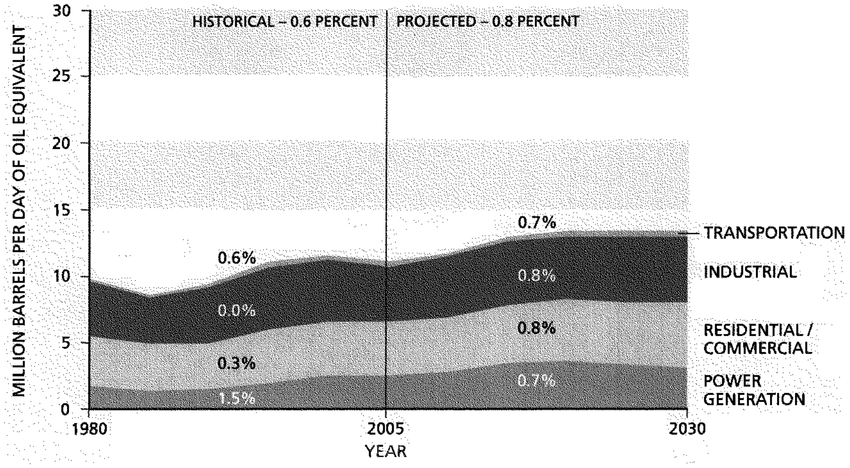

FIGURE 1-19. *U.S. Natural Gas Demand by Sector (EIA Reference Case) — Average Annual Growth Rates*

of the projected growth in coal demand from 2000 to 2030 is in China and India, where the economies are growing rapidly and coal is very competitive with other fuels. The indication is that share of total world energy consumption met by coal is projected to increase in all cases except where policies are enacted that place a limit on the use of coal.

Worldwide nuclear consumption growth in all outlooks is projected to be slower in the future than it has been in the past. The nuclear share of total worldwide energy demand declines in all projections except for the Alternative Policy Case, in which it increases very slightly. While the specific numbers are different in the U.S. projections, the trends are the same. The nuclear share of energy consumption is projected to decline slowly in the United States through 2030. The projections suggest that a major shift in nuclear policy will be required to increase the nuclear share of energy use.

The share of total worldwide energy consumption accounted for by other energy sources (hydro, biofuels, wind, solar, etc.) is projected to be higher in 2030 than in 2000.

As shown in Figure 1-20, worldwide carbon dioxide emissions grow in all of the projections. Carbon dioxide emissions are projected to range from 34 billion metric tons in 2030 in the IEA Alternative Policy Case to 51 billion metric tons in the EIA High Economic Growth Case, compared with 24 billion metric tons in 2000. In all cases, carbon dioxide emissions increase at about the same rate as energy demand. Carbon dioxide emissions in the United States are also expected to grow in all projections, although not as fast as for the world. In 2030, carbon dioxide emissions in the United States range from 6.3 billion metrics tons in the IEA Alternative Policy Case to 9 billion metric tons in EIA High Economic Growth Case (5.8 billion metrics tons in 2000).

The regional shares of energy use are projected to change over time. The share of total worldwide energy consumed in North America, OECD Europe, and Non-OECD Europe and Eurasia is projected to fall in all of the cases, while the share in Asia/Oceania grows. China is a major contributor to the substantial growth in Asia/Oceania share. In general, the change in the oil share of total worldwide oil consumed by region parallels the

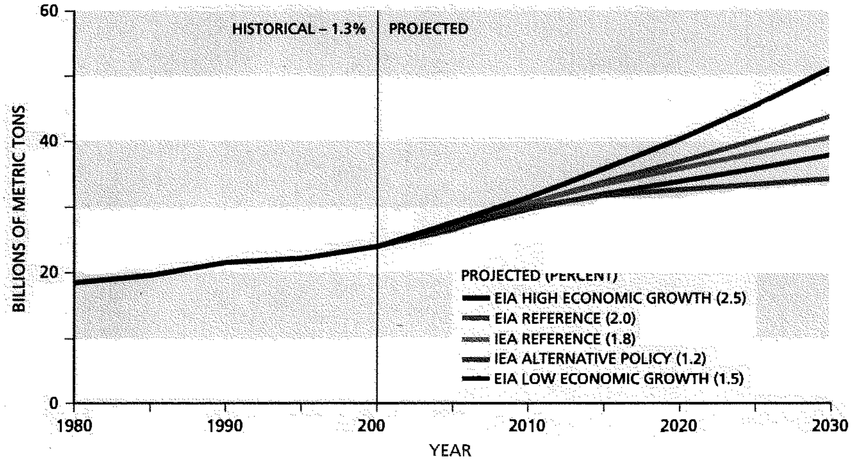

FIGURE 1-20. *World Carbon Dioxide Emissions — Average Annual Growth Rates*

change in the share of total energy consumption, with industrialized regions losing share and the Asia/Oceania oil share increasing significantly, as shown in Table 1-4.

Energy consumption per unit of GDP (energy intensity) is projected to decline in all regions. The Middle East, while not exhibiting the highest energy intensity in 2000, is projected to have the highest energy intensity in 2030 in all cases. North America, the region exhibiting the highest energy use per person in 2000, is still projected to have the highest energy use per person in 2030, but it declines in the IEA cases. Energy consumption per person in all other regions is projected to be higher than or equal to 2000 levels in 2030, as shown in Table 1-5.

Part of the study effort involved collecting energy demand projections from organizations other than EIA or IEA. Some of these projections were proprietary and, therefore, were collected by a third party with the data aggregated before being made available to study participants. Details of the aggregated data collection process are discussed in Chapter 7, "Methodology."

	2000 IEA	2030 IEA Ref Case
North America	27%	21%
Central and South America	5%	5%
OECD Europe	18%	13%
Non-OECD Europe & Eurasia	10%	8%
Middle East	4%	6%
Asia/Oceania	31%	41%
Africa	5%	6%

TABLE 1-4. *Regional Energy Shares*

The results of the aggregated proprietary data collection effort confirmed that using the EIA and IEA projections was reasonable. As can be seen on

	2003 IEA	2030 IEA Ref. Case
North America	9.51	6.18
Central and South America	6.53	4.58
OECD Europe	6.49	4.35
Non-OECD Europe & Eurasia	21.27	9.40
Middle East	15.23	12.04
Asia/Oceania	8.04	4.84
Africa	12.00	7.87

TABLE 1-5. *Regional Energy Intensity (1,000 Btu/2000$ GDP)*

Figure 1-21, the aggregated proprietary projections for all three levels of the total submissions output (average of the two highest submissions, average of the two lowest submissions, and the average of all submissions) fall generally in the range of the EIA and IEA projections for total energy. The same is true for all the major energy types.

For the U.S. situation, there were an insufficient number of submissions to provide a high and low average. Figure 1-22 shows that the average for the proprietary data is in the range of the EIA and IEA projections for total energy. Similar observations hold for major energy types.

Other studies were provided to the study effort as public projections. Generally, the information in these studies was in less detail than provided in the EIA and IEA studies. There were other organizations that had sufficient data available to provide partially complete data input templates. The other studies support the finding that the EIA and IEA projections provide a reasonable range of results for assessing energy issues. With the exception of the IEA Alternative Policy Case, policy assumptions underpinning the projections are extensions of polices in place today. It is interesting to note that projections with lower energy demand growth rates are based on lower economic growth rates. As an example of the congruence of study results, the energy and carbon dioxide growth rates are shown in Table 1-6. There were other projections

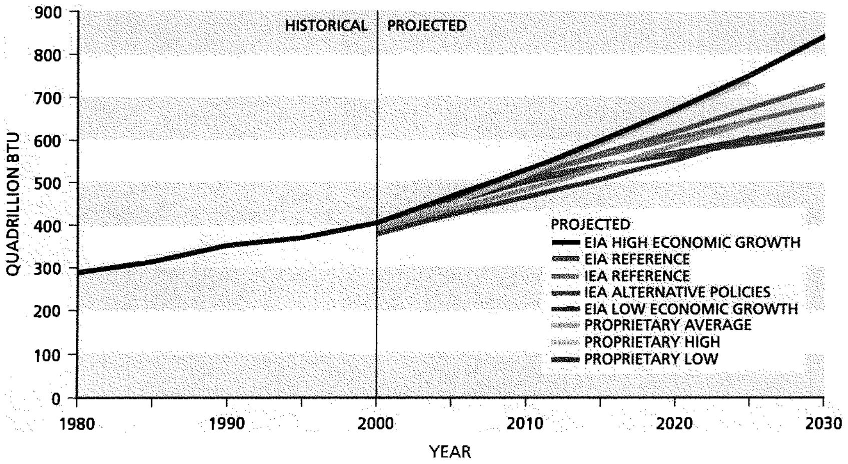

FIGURE 1-21. *World Energy Demand — Public and Proprietary Projections*

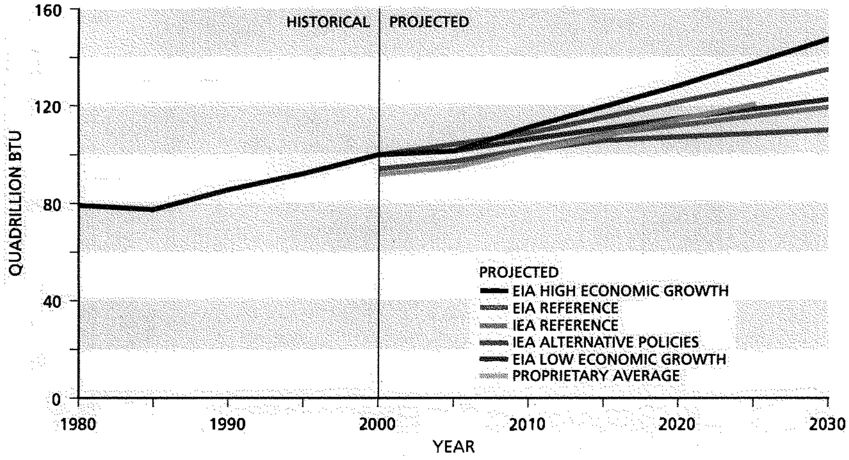

FIGURE 1-22. *U.S. Energy Demand — Public and Proprietary Projections*

	World Economy	World Population	World Energy	World CO_2
Energy Information Administration – reference	3.7%	1.0%	1.9%	2.0%
Energy Information Administration – low economic	2.9%	1.0%	1.4%	1.4%
Energy Information Administration – high economic	4.5%	1.0%	2.5%	2.5%
International Energy Agency – reference	2.7%	1.0%	1.6%	1.7%
International Energy Agency – alternative policy	2.4%	1.0%	1.2%	1.0%
European Commission	3.1%	0.9%	1.7%	1.8%
Institute of Energy Economics, Japan	3.1%	1.0%	1.7%	1.8%
Greenpeace & European Renewable Energy Council	3.1%	0.9%	1.4%	1.5%
U.S. Climate Change Science Program – MERGE	2.6%	0.8%	1.0%	1.2%
U.S. Climate Change Science Program – MINICAM	2.3%	0.9%	1.7%	1.5%
U.S. Climate Change Science Program – IGSM	3.1%	1.0%	1.9%	2.1%

TABLE 1-6. *Outside Study Comparison of Average Annual Growth Rates from 2004 to 2030*

that were submitted or captured in other efforts that did not have sufficient definition of underlying bases or data detail to be included in the comparison.

The Petroleum Federation of India (PFI) provided a series of outlooks for India. These projections offer perspective on the expected Indian energy situation. The data are limited, but there is sufficient information to look at the 2020 energy mix. The PFI total energy projection has a 2004 to 2020 energy demand growth rate of 3.3 percent per year for the Business as Usual Case. This growth rate is slightly higher than the 3.0 and 2.8 percent per growth rates developed in the EIA and IEA Reference Cases, respectively. One difference between the projections is in petroleum demand, where the PFI projection has an indicated 2004 to 2020 growth rate of 4.7 percent per year while the other two projections have indicated growth rates of 2.6 to 3.2 percent per year. Offsetting this difference, to some extent, is the lower growth in coal use expected by PFI relative to the other projections.

McKinsey Global Institute conducted a study in November 2006 that approached the issue of the potential for energy savings (*Productivity of Growing Global-Energy Demand: A Microeconomic Perspective*). The study provides an assessment of potential savings without regard for the time needed to achieve the estimated savings, or for the practicality of achieving them. The McKinsey study used 2020 as its horizon year. As indicated in Table 1-7, the McKinsey study suggests that between 2003 and 2020 essentially all U.S. energy growth, and about 75 percent of world energy growth, could be recovered by efficiency/conservation measures assuming they could be instituted within the time period. The McKinsey study adds support to the NPC study recommendations that efficiency/conservation measures are an important piece for providing a balanced U.S. energy program.

When preparing its International Energy Outlook, the EIA uses the Annual Energy Outlook as a major source of U.S. data. The EIA released an updated version of its Annual Energy Outlook during the first quarter of 2007. Table 1-8 contains a 2004 to 2030 growth rate comparison between the 2006 and 2007 Annual Energy Outlooks. There are only

	McKinsey		EIA	
	U.S.	**World**	**U.S.**	**World**
Energy consumption				
2003 – quadrillion Btu	92	422	101	433
2020 – quadrillion Btu	113	615	121	613
Growth – percent per year	1.2%	2.2%	1.0%	2.1%
2020-2003 – quadrillion Btu	21	193	19	181
Potential 2020 reduction				
Low estimate – quadrillion Btu	19	117	19	117
High estimate – quadrillion Btu	27	173	27	173
Percent of 2003 to 2020 growth				
Low – percent	90%	61%	100%	65%
High – percent	129%	90%	140%	96%

Sources: McKinsey Global Institute, *Productivity of Growing Global-Energy Demand: A Microeconomic Perspective*, November 2006; Energy Information Administration, *Annual Energy Outlook 2007*.

TABLE 1-7. *Comparison of Data from McKinsey Global Institute and Energy Information Administration*

	AEO 2006	AEO 2007
Primary Energy		
Petroleum Products	1.1%	1.0%
Natural Gas	0.7%	0.6%
Coal	1.7%	1.6%
Nuclear	0.4%	0.5%
Other	1.7%	1.6%
Total	1.1%	1.1%
Sectors		
Residential	0.8%	0.7%
Commercial	1.6%	1.6%
Industrial	0.3%	0.7%
Transportation	1.4%	1.3%
Electric Generation	1.3%	1.2%
Subtotal	1.2%	1.1%
Electricity	1.6%	1.4%
Total	1.1%	1.1%
Gross Domestic Product	3.0%	2.9%

TABLE 1-8. *Comparison of EIA Annual Energy Outlook 2006 and 2007 Reference Cases' Average Annual Growth Rates from 2004 to 2030*

minor differences between the two projections, which suggests that the overall analysis that uses the 2006 International Energy Outlook (IEO 2006) is basically unchanged as a result of the recently released EIA U.S. outlook. Data availability issues have lead to some of the analyses that support various components of the demand effort being based on the AEO 2007, which should not present any difficulties.

The EIA released the 2007 version of the International Energy Outlook (IEO 2007) on May 21, 2007. IEO 2007 suggests no changes in the overall demand related conclusions of the National Petroleum Council's Global Oil and Gas Study. However, there are some interesting differences between IEO 2006 and IEO 2007 that should be noted. A comparison between the two Reference Case outlooks is shown in Table 1-9.

World economic growth is higher in IEO 2007. From a regional perspective, the major differences are in Asia/Oceania where projected economic growth is faster, and in North America, where it is slower. All other regions show a greater growth in economy than in IEO 2006 with the Non-OECD Europe and Eurasia region projected difference slightly greater than in other regions.

While the economic growth projections used as a basis for IEO 2007 are generally greater than in IEO 2006, energy growth projections are equal or less than they were in IEO 2006. This suggests that the energy efficiency/conservation assumptions underpinning IEO 2007 are greater than in IEO 2006. Energy intensities (energy use per unit of economic activity) calculated from the two outlooks show that in all regions except North America energy intensity is lower in IEO 2007, supporting the idea that there is more energy efficiency/conservation incorporated in IEO 2007 than in IEO 2006.

The projected regional energy consumption pattern in IEO 2007 is little different than in IEO 2006. The biggest difference is in Asia/Oceania, where projected 2030 energy use share increased from 37.6 percent to 39.2 percent.

Considering the type of energy consumption, the most significant difference appears to be a lower projection of world natural gas use. Both nuclear and coal use are projected to be higher. There was an accounting convention change between the two outlooks for the way in which renewable liquids were handled. In IEO 2007, liquids from renewables are shown as petroleum products instead of as "other." This change accounts for most of the reduction in other energy use, but suggests that petroleum liquids from more traditional sources are somewhat lower in IEO 2007 than in IEO 2006.

An output from both projections is an estimate of carbon dioxide emissions. In 2030, the IEO 2006 estimate for Reference Case carbon dioxide emissions was 43.7 billion metric tons. The IEO 2007 carbon dioxide emissions estimate for 2030 is 42.9 billion metric tons.

	2003-2030		2030	2030	2007-2006	2030	2030
	Growth Rate (%/Year)		Share (%)		Difference (Quadrillion Btu)	Intensity (1,000 Btu/ 2005$ GDP)	
	IEO 2006	IEO 2007	IEO 2006	IEO 2007		IEO 2006	IEO 2007
Primary Energy							
Petroleum Products	1.4%	1.4%	33.1%	34.1%	-0.2		
Natural Gas	2.4%	2.0%	26.3%	24.3%	-19.5		
Coal	2.5%	2.6%	27.1%	28.4%	3.8		
Nuclear	1.0%	1.3%	4.8%	5.7%	5.0		
Other	2.4%	1.8%	8.6%	7.6%	-8.9		
Total	2.0%	1.9%	100.0%	100.0%	-20.0		
Regions (Energy)							
North America	1.3%	1.2%	23.0%	23.0%	-4.6	5.98	6.01
OECD Europe	0.7%	0.5%	13.1%	12.7%	-5.3	4.87	4.48
Central and South America	2.6%	2.4%	6.3%	5.9%	-4.5	5.49	4.67
Middle East	2.5%	2.3%	5.2%	5.4%	0.5	9.23	9.03
Non-OECD Europe and Eurasia	1.8%	1.4%	10.9%	10.2%	-7.5	8.80	7.24
Africa	2.6%	2.3%	3.7%	3.5%	-1.9	3.61	3.36
Asia/Oceania	3.1%	3.1%	37.6%	39.2%	3.2	4.20	3.58
Total	2.0%	1.9%	100.0%	100.0%	-19.9	5.14	4.55
Gross Domestic Product (billion 2000 dollars)					**Difference ($ $2000)**		
North America	3.1%	2.9%	19.8%	17.4%	849		
OECD Europe	2.3%	2.3%	13.8%	12.3%	519		
Central and South America	3.8%	4.0%	5.5%	5.7%	541		
Middle East	4.2%	4.3%	2.8%	2.7%	145		
Non-OECD Europe and Eurasia	4.4%	4.7%	6.5%	6.4%	691		
Africa	4.4%	4.6%	5.0%	4.8%	438		
Asia/Oceania	4.8%	5.5%	48.1%	50.8%	12,458		
Total	3.8%	4.2%	100.0%	100.0%	13,983		

TABLE 1-9. *Comparison of EIA International Energy Outlook — 2006 and 2007 Reference Cases*

ELECTRIC GENERATION EFFICIENCY ◆

Power plant efficiencies presented in the EIA and IEA outlooks both show improvements over time. These expected improvements mainly come from the replacement of retired old plants with new plants that have better efficiencies. There are a few changes that can be made to make an existing unit more efficient. However, these changes typically will only result in a few percentage point improvements to efficiency.

Given the large aggregate capacity of existing coal-fired power plants and their long useful lives, efforts to improve the average efficiency of the existing stock by 1 or 2 percent could have a significant near term impact on fuel consumption rates and greenhouse gas emissions. Efficiency improvement potential for existing U.S. power plants is related to the age of the plant, the age of specific pieces of equipment in a plant, a plant's design, and the economics of the specific plant situation. When all is considered, most plants will fall in the 3-6 percent range of possible improvement. The practical or economic values will be lower. The newer plants might be in the 2-4 percent range and a certain population might be 2 percent or less because they were already upgraded. The overall range of potential efficiency improvement for existing U.S. coal fired power plants should be in the 2 to 4 percent range.[2]

Much of the discussion surrounding power plant efficiency will focus on the heat rate (Btu per kilowatt-hour). This is an ideal measure of efficiency since it defines the ratio of the input as fuel (Btu) to output as power (kilowatt-hour). The efficiency of a new power plant is largely a function of economic choice. The technology is well understood in order to produce a highly efficient plant. In order to produce higher efficiencies, higher pressures and temperatures are required. This increases the cost of the plant as special alloy materials will be needed. Technology improvements could assist by lowering the cost of these special materials through discovery and better manufacturing process.

Coal power plant efficiency merits much focus since coal represents over 50 percent of current generation in the United States. Many countries in the world from Germany to Japan have demonstrated coal plants with heat rates of less than 9,000 Btu per kilowatt-hour. The United States has also demonstrated such technology since the 1950s. However, the U.S. coal fleet current operating heat rate is nowhere near those levels, at 10,400 Btu per kilowatt-hour.

Existing coal-fired power plants worldwide do not achieve the highest efficiency possible based on their design. The efficiency loss can be categorized as controllable or non-controllable. Controllable losses are generally due to poor operation and maintenance practices. Non-controllable losses are due to environmental conditions (e.g., cooling-water temperature), dispatching requirements (e.g., customer demand), and normal deterioration.

Deterioration naturally occurs and, if left unchecked, can become substantial. Therefore, some amount of normal deterioration will always be present and non-controllable. Most of the normal deterioration can be recovered with regularly scheduled maintenance intervals, the frequency of which determines the average based on the resulting saw-tooth curve shown in Figure 1-23. There is a gradual increase in the unrecoverable portion as the unit ages, which would require a replacement rather than a refurbishment to eliminate. Poor maintenance practices regarding the timing of the intervals and the amount of refurbishment may result in excessive deterioration and is controllable.

Figure 1-24 shows historical and projected heat rates from U.S. natural gas and coal-fired power plants. Historical calculations are based upon EIA data that include both central station generation and end-use generation of electricity. The post-war boom of the late 1940s and 1950s saw a large increase in new power plants. However, these were, by today's standards, highly inefficient plants, with the overall fleet heat rate starting in 1949 at nearly 15,000 Btu per kilowatt-hour. By the end of the 1950s, more-efficient plant constructions drove the fleet heat rate to about 10,300 Btu per kilowatt-hour, where it remained relatively unchanged until the end of the century.

The overbuilding of natural gas combined-cycle units in the late 1990s decreased the natural gas fleet heat rate below 9,000 Btu per kilowatt-hour, where it currently resides. However, with the recent higher natural gas prices, coal generation still represents over 50 percent of current U.S. power generation. Therefore, overall U.S. fleet heat rate was not affected by the large gas combined-cycle build since coal-fired heat rates remain around 10,400 Btu per kilowatt-hour.

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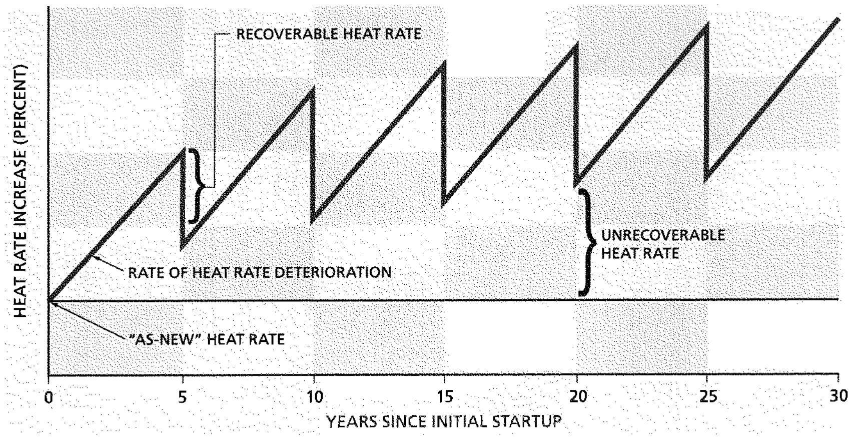
[2] Equipment Refurbishing and Upgrading Options (taken from Asia Pacific Economic Cooperation document, June 2005).



Source: General Electric GER-3696D, *Upgradable Opportunities for Steam Turbines*, 1996.

FIGURE 1-23. *Change in Heat Rate over Time*

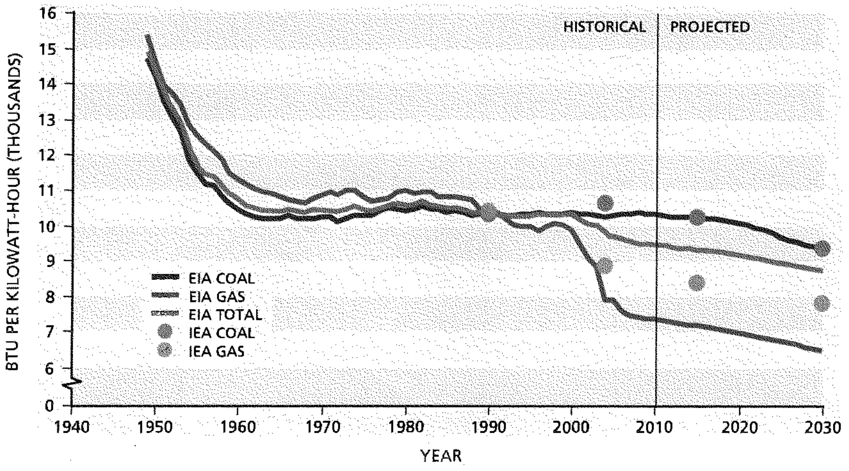


FIGURE 1-24. *U.S. Operating Heat Rates*

The EIA is projecting the natural gas fleet heat rate to continue to improve. Around the year 2023, electricity generation from natural gas units decreases faster than consumption, resulting in a slight increase to 8,300 Btu per kilowatt-hour. Currently, best technology combined-cycle units can achieve ~5,700 Btu per kilowatt-hour [General Electric H-System]. The gas heat rate includes combustion turbine plants that could have heat rates as high as 13,000 and as low as 8,550 Btu per kilowatt-hour in the future according to the EIA. These types of units will continue to be needed as they have the ability to turn on and off over a short time period leading to increased system stability.

The EIA projects moderate improvements in the coal fleet heat rate, achieving 9,700 Btu per kilowatt-hour by 2030. In terms of percentage improvement, it is about the same trend as gas units. This indicates many more new coal plants as compared to new gas plants in the projection. To see any appreciable improvement in fleet heat rate, a large number of new, efficient units would need to replace a large number of old, inefficient units and/or existing units would have to be retrofitted. With 40-year life spans and high capital costs (vs. natural gas plants) to construct, and risk of a CO_2-constrained environment, this is not achieved very quickly. The difference in fuel price (coal vs. natural gas) is another major driver for increased efficiencies in gas plants compared to coal plants. Major increases in combined-cycle efficiencies will make those units more competitive with coal in dispatch. With coal's current fuel price advantage, there is less incentive to make wholesale improvements in efficiency versus focusing on availability. Table 1-10 shows the EIA assumptions for new build heat rates for 2005, n^{th}-of-a-kind plant in the future and the best observed heat rates to date. Observed data for combustion turbines are not provided because efficiency is not their primary role in the supply stack. These units are used primarily as peakers, where efficiency is not of utmost concern.

Because historical data do not align properly between EIA and IEA due to differences in data definitions, heat-rate improvements were examined for the world and China, as opposed to absolute heat-rate values. Figures 1-25, 1-26, 1-27 show the percentage improvements in heat rate for EIA and IEA from each agency's base year. As expected, heat-rate inprovements in

Technology	Heat Rate in 2005	Heat Rate n^{th}-of-a-Kind (% Improvement from 2005)	Best Current (2004)*
Scrubbed Coal	8,844	8,600 (2.8%)	8,842†
Integrated Gasification Combined Cycle (IGCC)	8,309	7,200 (13.3%)	N/A
IGCC w/carbon sequestration	9,713	7,920 (18.5%)	N/A
Conventional Combined Cycle	7,196	6,800 (5.5%)	6,335‡
Advanced Combined Cycle	6,752	6,333 (6.2%)	N/A
Advanced Combined Cycle w/carbon sequestration	8,613	7,493 (13.0%)	N/A
Conventional Combustion Turbine	10,842	10,450 (3.6%)	N/A
Advanced Combustion Turbine	9,227	8,550 (7.3%)	N/A

* "Operating Performance Rankings Showcase Big Plants Running Full Time," Electric Light & Power, Nancy Spring, managing editor, November 2005.
† Coal = TVA, Bull Run Plant.
‡ Conventional Combined Cycle = Sempra, Elk Hills Power.

TABLE 1-10. *EIA Heat-Rate Assumptions (Btu per Kilowatt-Hour)*

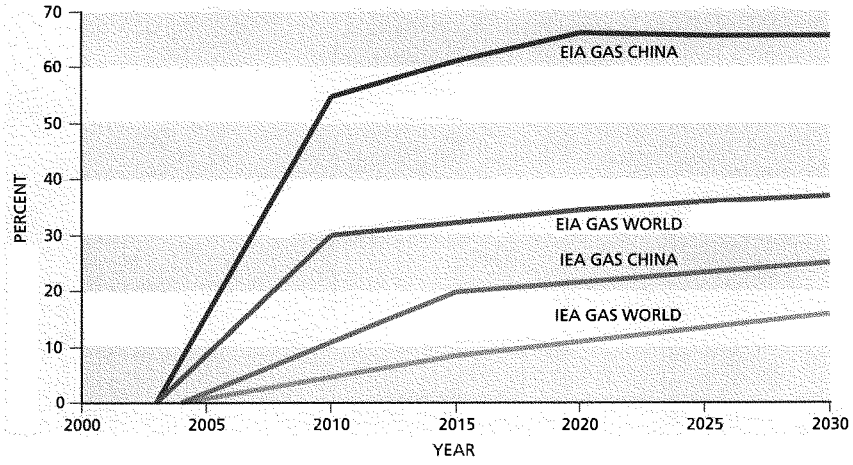


FIGURE 1-25. *Natural Gas Heat Rate Improvements*

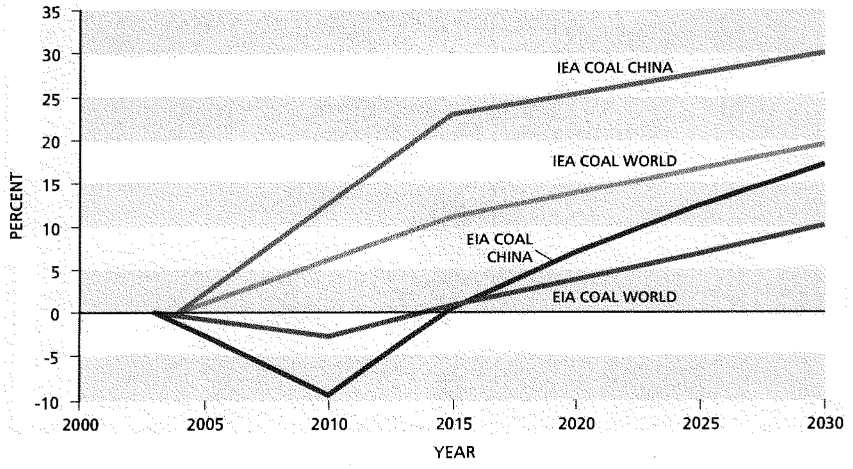


FIGURE 1-26. *Coal Heat Rate Improvements*

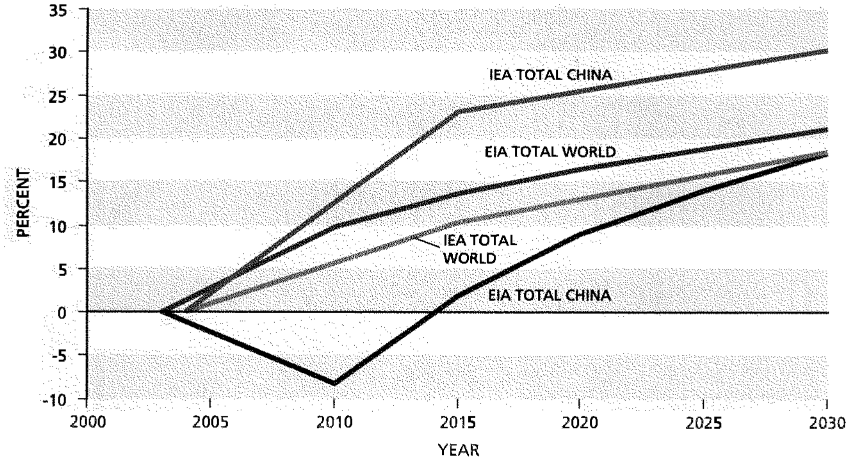
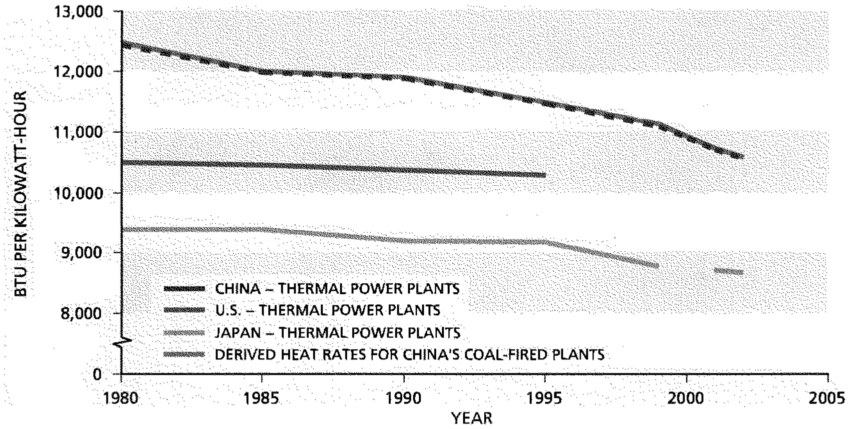


FIGURE 1-27. *Total Heat Rate Improvements*

China are projected to outpace worldwide improvements. Rapidly growing power demand is expected to drive a large increase in the number of new builds. With a larger percentage of fleet capacity coming from newer, efficient units, it is expected that overall improvements would increase rapidly in China. Worldwide heat-rate improvements are projected to increase moderately for both gas and coal plants according to both EIA and IEA. Again, this is the result of gradual replacement of older, inefficient units that have outlived their economic lives with new, efficient ones. The slower pace of this replacement leads to the slower increase in efficiency when compared with China alone.

An important distinction to note between the EIA and IEA projections is the heat-rate improvements for coal and natural gas. The EIA projects natural gas improvements for the world and China to greatly outpace improvements to coal-fired generation. Inversely, the IEA projects coal to improve more rapidly than for natural gas-fired plants. There are two schools of thought that can justify either scenario. One could argue that gas heat rates are expected to rapidly improve due to a large buildup of highly efficient combined-cycle units. This is the same phenomenon that was seen in the United States during the 1990s. With a rapid increase of combined-cycle units, the gas heat rate quickly improves. The large improvements in coal-fired heat rates could be justified by determining that gas-fired heat rates are asymptotically approaching their maximum achievable efficiency (though not achievable, 100 percent efficiency is 3,412 Btu per kilowatt-hour). Steam cycle coal units theoretically have more room for improvement since they are less efficient from the start.

Recently, a blue book of energy in China (The Energy Development Report of China, Edited by M. Cui, etc., Social Sciences Academic Press of China, 2006) reports that the average heat rates of thermal power plants in China improved 15.2 percent from 1980 to 2002. Figure 1-28 shows the average heat rates of thermal power plants in China, compared with those in the United States and Japan. Natural gas consists of only a small percentage of China's energy mix on a Btu basis. For example, natural gas comprised only 2.62 percent in 2002, in comparison to 65.28 percent for coal. In 2002, 54.7 percent of coal consumption in China went to power plants, and the report does not give the percentage of natural gas consumed by the power plants, but states that most of its natural gas went to residential use. The IEA World Energy



Source: The Energy Development Report of China, Edited by M. Cui, etc., Social Sciences Academic Press of China, 2006.

FIGURE 1-28. Historical Heat Rates

Outlook 2006 reports the electricity generation from thermal power plants. For China, coal consists of more than 90 percent of thermal power generation since 1990, and continues to increase its share.

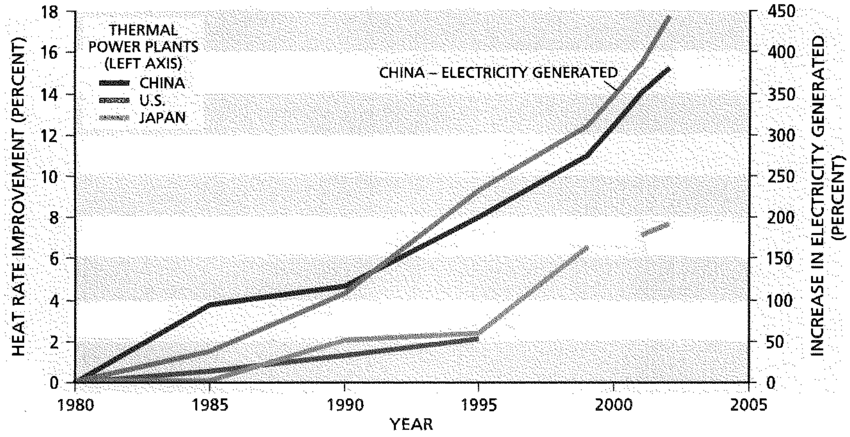
Japan has the lowest coal percentage in its thermal-generated electricity of the three countries. To conservatively estimate the average heat rate for Chinese coal-fired power plants, it is assumed that 1 percent of electricity generated from thermal power plants came from natural gas before 2004, and assume that the average heat rate of gas-fired plants is 30 percent better than that of coal-fired plants and that the average heat rate of oil-fired power plants is the same as that of coal-fired power plants. The derived heat rates for coal-fired plants in China are about 0.2 percent higher than the average heat rates of its thermal power plants. Of the three countries, China had improved its thermal power plants efficiency the most from 1980 to 2002. The great improvement in efficiency in the thermal power plants in China can be attributed to a large number of new builds. Figure 1-29 also shows increases in China's electricity output in the same period, of which the coal-fired plants contributed the most. For example, thermal power plants generated 82.64 percent of electricity in China in 2004. The large percentage of higher-efficiency coal-fired new builds drives China's average heat rates down quickly.

COAL IMPACT ✦

The primary consumer of coal in the United States is the electric power industry, consuming 92 percent of the 1.1 billion tons used in 2005. About half the U.S. electricity generated in 2005 was from coal. EIA projects that coal consumed to generate power in the electricity sector will account for 85 percent of total U.S. coal consumption by 2030 (Figure 1-30). In the AEO 2006 Reference Case projection, the emergence of a coal-to-liquids (CTL) industry accounts for virtually all of the growth in coal use in the non-electricity sectors.

Coal is consumed in large quantities throughout the United States. As shown in Figure 1-31, coal production is focused in relatively few states, meaning that huge amounts of coal must be transported long distances. Therefore, U.S. coal consumers and producers have access to the world's most comprehensive and efficient coal transportation system.

All major surface-transportation modes carry large amounts of coal. According to the EIA, about two-



Source: The Energy Development Report of China, edited by M. Cui, etc., Social Sciences Academic Press of China, 2006.

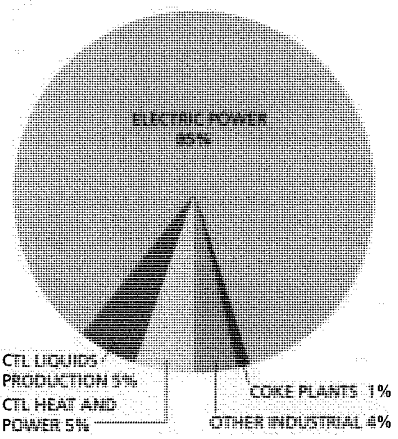
FIGURE 1-29. *Changes in Efficiency and Electricity Generated in China*

thirds of U.S. coal shipments were delivered to their final domestic destinations by rail in 2004, followed by truck (12 percent), the aggregate of conveyor belts, slurry pipelines, and tramways (12 percent), and water (9 percent, of which 8 percent were inland waterways and the remainder tidewater or the Great Lakes).[3]

Over the past 15 years, the rail share of coal transport has trended upward, largely reflecting the growth of western coal moved long distances by rail. The truck share has fluctuated, but has also trended upward since 1990, while the waterborne share has fallen.

The extent to which coal is able to help meet U.S. future energy challenges will depend heavily on the performance of coal transporters. If the past is a reliable guide, the various modes will be able to accommodate increased coal transportation demand, albeit perhaps with occasional "hiccups" and "bottlenecks" along the way.

Railroads, barges, and trucks are all critical coal transportation providers. Each mode faces challenges,



Source: EIA, *Annual Energy Outlook 2006.*

FIGURE 1-30. *U.S. Coal Consumption by Sector — 2030*

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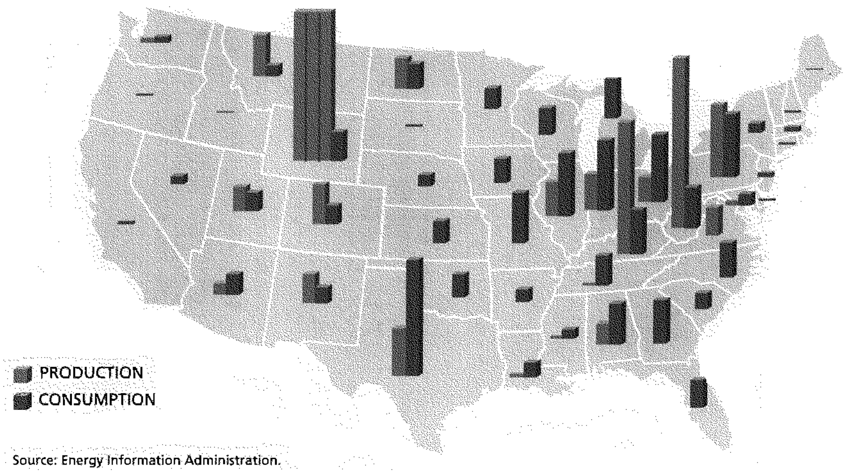
[3] Energy Information Administration, "Coal Distribution Current and Back Issues," web site www.eia.doe.gov.



Source: Energy Information Administration.

FIGURE 1-31. *U.S. Coal Consumption and Production by 2005*

some of which are unique to it and some of which are common to each of the modes. For each mode, having capacity that is adequate to meet growing demand is perhaps the most pressing need.

Available truck capacity will be determined by factors such as the amount of public spending on highways, how well the industry resolves the driver retention issue, and fuel costs.

Like trucks, waterways depend on publicly owned and maintained infrastructure. Waterway infrastructure is, in general, in need of significant maintenance and improvement. The availability of public funds to provide these improvements will feature prominently in how well waterways can handle future coal-transportation needs.

Railroads, on the other hand, rely overwhelmingly on privately owned, maintained, and operated infrastructure. As private-sector companies, railroads must be confident that traffic and revenue will remain high enough in the long term to justify the investments before they expand capacity. Railroads will continue to spend huge amounts of private capital to help ensure that adequate capacity exists, but they can do so only if regulations or laws do not hinder their earnings.

Worldwide, coal trade patterns have shown a steady evolution since the early days of the international coal industry. As long ago as the early 1980s, Australia was still a minor coal exporter. Indonesia, now the world's largest thermal coal exporter, did not emerge as a force in the international market until the 1990s. A similar pattern exists on the demand side. In the 1970s, there was regional trade in Europe with supply coming from Germany and Poland. The 1980s were dominated by Japan's demand for coal, while the 1990s saw Korea and Taiwan as significant markets. The early years of this decade have seen rapid increases in demand from smaller countries in Asia, as well as the emergence of China as both a significant coal exporter and a major import market.

Trade patterns are hard to project because some countries have dedicated export facilities as well as mines that are intended for purely domestic purposes. The current major exporters of coal are Indonesia, Australia, China, South Africa, Russia, and Colombia. All of these countries, except Indonesia and China, have current reserves-to-production ratios in excess of 100.

INDUSTRIAL EFFICIENCY ◆

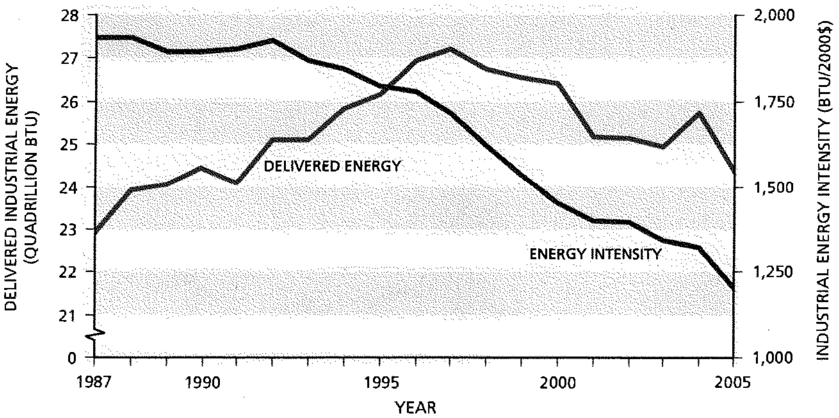
The industrial sector is a large and price-responsive consumer of energy, consuming roughly one-third of the energy used in the United States. U.S. energy-intensive industry and manufacturers in associated value chains rely on competitive energy supplies to remain globally competitive.

As natural gas prices have risen in the United States relative to those in the rest of the world, manufacturers with energy-intensive processes have responded in two ways: (1) by increasing the efficiency of their operations (shown as energy intensity on Figure 1-32), and/or (2) by shifting a greater proportion of energy-intensive industry outside the United States (shown by declining industrial energy use).

Despite this decrease in energy intensity, energy-intensive manufacturers in the United States struggle to remain competitive in the global marketplace. U.S. manufacturers are investing for strategic growth in regions of the world where energy costs are lower. For example, over the last 10 years, the United States has gone from one of the world's largest exporters of chemicals to an importer. Although less dramatic, trends are similar in the paper and metals industries. Figure 1-33 tracks the aggregate trade balance for the steel, paper, and chemicals industries compared to the price of natural gas. Significantly, the correlation between the two data series is -89 percent, indicating that high natural gas prices have hurt U.S. competitiveness in these industries.

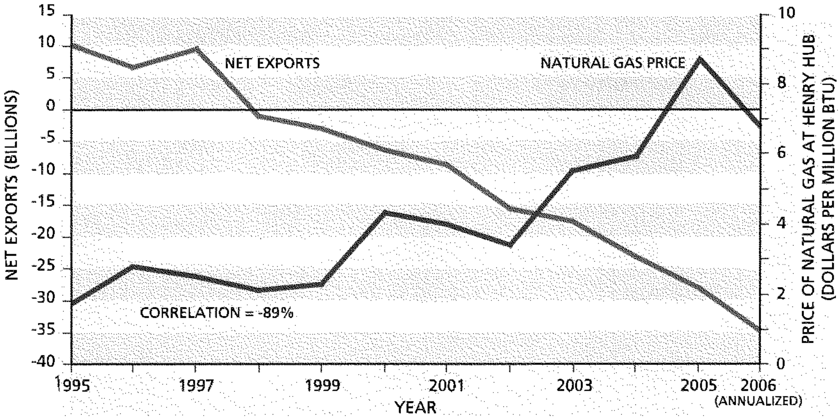
The extent to which U.S. industry can continue to compete for the domestic market is unclear. For instance, imports have provided 40 percent of the increase in U.S. gasoline use over the last 10 years. The impact of factors such as international supply and demand balances for oil and natural gas, geopolitical issues, the advent of disruptive technologies, and the evolution of the world's economies is unknown. The uncertainty in U.S. industrial energy consumption carries through to global balances. Since product consumption is unlikely to decline, product needs that are unmet by local production likely will be met by imports.

Projecting historical industrial energy patterns forward may illustrate this uncertainty. In the first scenario (called Stays), industrial use grows as it did between 1983 and 1996. In the second scenario (Flight), industrial consumption declines as it



Sources: Delivered Industrial Energy Consumption data from EIA, *Annual Energy Review 2005*.
GDP data from Bureau of Economic Analysis website.

FIGURE 1-32. *U.S. Industrial Energy Consumption and Energy Intensity*



Source: U.S. Dept. of Commerce data for SITC Code 5 (Chemicals and Related Products), 64 (Paper and Paperboard), and 67 (Iron and Steel) from tse.export.gov web site. Price data from Platt's.

FIGURE 1-33. *Trade Balance for Energy-Intensive Industry*

did between 1996 and 2005. These projections are intended to bound the EIA's AEO 2007 Base Case projection. Energy use growth rates for each are shown in Table 1-11 and depicted in Figure 1-34.

Bandwidth studies conducted for the U.S. DOE on the most energy-intensive manufacturing sectors (chemical, petroleum, and forest products industries) suggest energy-efficiency opportunities of up to 5 quadrillion Btu per year, or just under 15 percent of 2005 industrial energy use. Of these opportunities, about 2 quadrillion Btu per year can be achieved by using existing technology (Table 1-12). Processes requiring additional research and development include separation, distillation, catalysts, alternate feedstocks, fouling, heat integration, drying, forming, and pressing.

Adopting existing technology for combined heat and power systems (CHP) and implementing "best practices" for steam systems would each yield savings of about 1 quadrillion Btu per year without requiring significant research. Despite its thermal efficiency advantages, CHP implementation in the U.S. industrial sector totals 72 gigawatts, which is about 50 percent of the total potential for CHP in the industrial sector (CHP Installation Database and Onsite Energy, 2000).

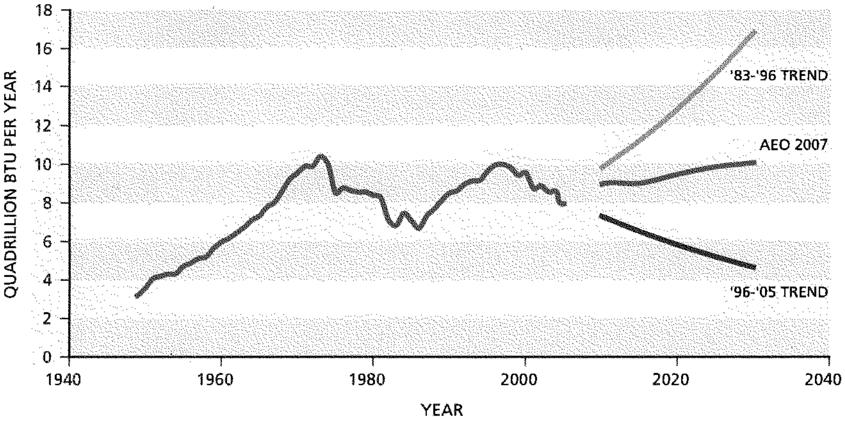
AEO 2007 projects a wide range of energy-intensity improvements in the manufacturing sector from 2005 to 2030, reflecting expected changes in that sector given

Growth Rates	Total Energy	Oil	Natural Gas
1949-1973	3.6%	3.9%	4.8%
1996-2005	-1.1%	0.5%	-2.2%
1985-1996	1.7%	1.4%	2.7%
Base 2005-2030	0.7%	0.4%	0.7%
High 2005-2030	-1.1%	0.5%	-2.2%
Slow 2005-2030	1.7%	1.4%	2.7%

Note: Growth rates average 2004/2005 values as a starting point to minimize the impact of Hurricanes Katrina and Rita on growth rate calculations.

Source: EIA, Table 2.1.d Industrial Sector Energy Consumption, 1949-2005, and *Annual Energy Outlook 2007.*

TABLE 1-11. *U.S. Industrial Energy Use Scenarios*



Source: EIA, Table 2.1.d Industrial Sector Energy Consumption, 1949-2005, and *Annual Energy Outlook 2007.*

FIGURE 1-34. *U.S. Industrial Energy Use Scenarios*

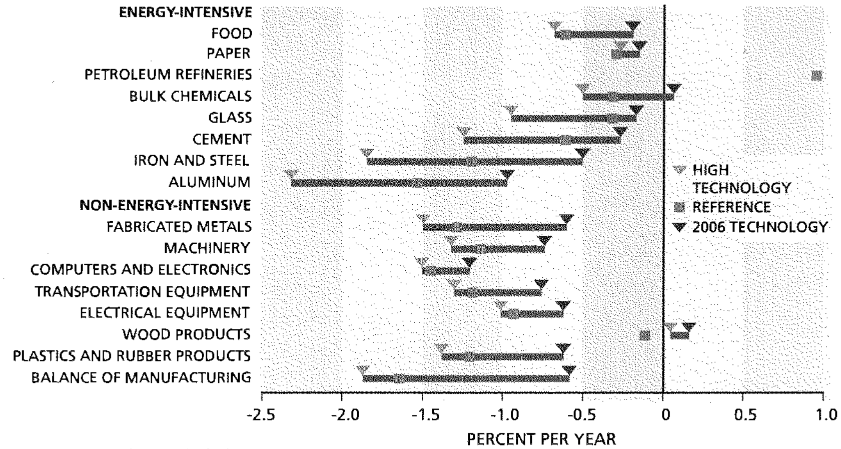
current conditions and trends. For example, the energy intensity of the aluminum sector is expected to decrease as secondary smelting, a less energy-intensive process, becomes the dominant technology in the United States. On the other hand, the energy intensity of the petroleum refining industry is expected to increase as liquids from coal come into use (Figure 1-35).

There are significant impediments to greater industrial efficiency. First, U.S.-government-funded energy R&D has fallen at least 70 percent in real terms from its peak in the late 1970s. Second, price volatility makes approval of efficiency projects difficult. Finally, lack of adequate, technically trained human resources impedes implementation of efficiency projects. Figure 1-36

Opportunity	Size (Quadrillion Btu per Year)	R&D Required?
Waste Heat Recovery	0.9	Yes
Industrial Boilers, Heat Recovery from Drying	0.8	Yes
Adoption of Best Practices in Heat and Power Systems and Steam Systems	0.9	No
Other – Requiring R&D	1.4	Yes
Other – Implementing Best Practices	1.1	No

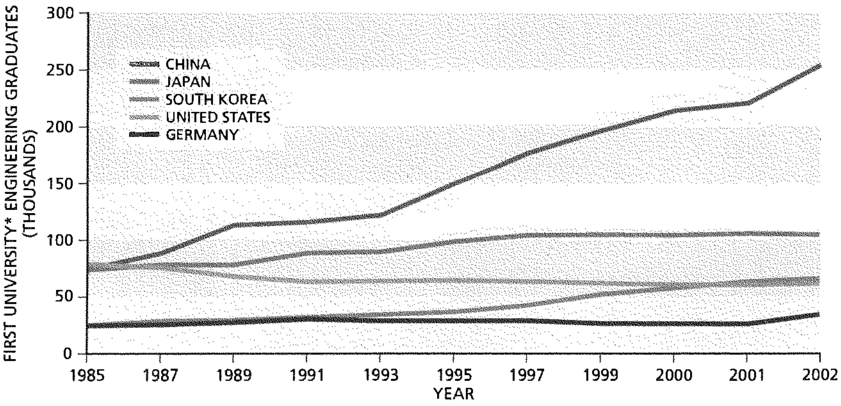
Source: *U.S. Department of Energy,* Energy Use, Loss and Opportunities Analysis: U.S. Manufacturing and Mining, *2004.*

TABLE 1-12. *Approximate Size of Efficiency Technology Opportunities*



Source: EIA, *Annual Energy Outlook 2007.*

FIGURE 1-35. *Average Change in Energy Intensity in the Manufacturing Subsectors, 2005-2030*



* International equivalent to a bachelor's degree.

Source: "U.S. Manufacturing Innovation at Risk," a study by Joel Popkin and Kathryn Kobe for The Manufacturing Institute and the Council of Manufacturing Associations, February 2006.

FIGURE 1-36. *Engineering School Graduates, by Year*

shows the number of engineering-school graduates per year from several countries.

Industrial energy consumers play an important role in mitigating energy price volatility. Manufacturing provides a quick-acting buffer against supply or demand shocks in the energy industry. However, as demonstrated in Figure 1-37, this role has been reduced as the U.S. capability for fuel switching has fallen over the past decade, in both the power generation and industrial sectors.

CULTURAL/SOCIAL/ECONOMIC TRENDS ✦

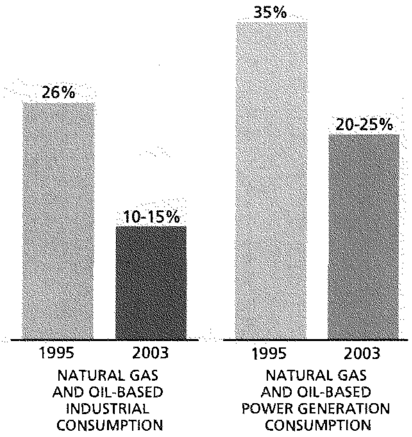
This area of investigation is extremely broad. However, after an analysis of the data, the following eight broad findings became apparent. The data analysis relied heavily on the Reference Case projections in WEO 2006 and IEO 2006.

1. **Income is the biggest determinant of demand for energy.**

Due to the strong influence of income on energy demand, even small changes in assumptions about the Gross Domestic Product (GDP) have major implications for energy growth. Energy projections by the IEA and EIA are highly sensitive to GDP assumptions. In WEO 2006, a 1 percent growth in global GDP results in a 0.5 percent increase in primary energy consumption. This is consistent with the observation that the income elasticity of demand fell from the 0.7 in the 1970s to the 0.4 from 1991-2002 as shown in Figure 1-38. WEO 2006 cites warmer winter weather in the northern hemisphere (which reduced heating-fuel demand) and improved energy efficiency for the reduction in income elasticity for energy as a whole between the two periods.

Assuming that projected economic growth is desired, then to maintain current U.S. energy consumption would require a 45 percent reduction in energy intensity by 2030. To maintain current developing-country energy consumption levels would require a 70 percent reduction in global energy intensity by 2030. Put in perspective, over the last 55 years (1949-2005), U.S. energy intensity has fallen by a little more than half (Figure 1-39). To maintain energy consumption at current levels would require a global reduction in energy intensity of roughly twice that amount.

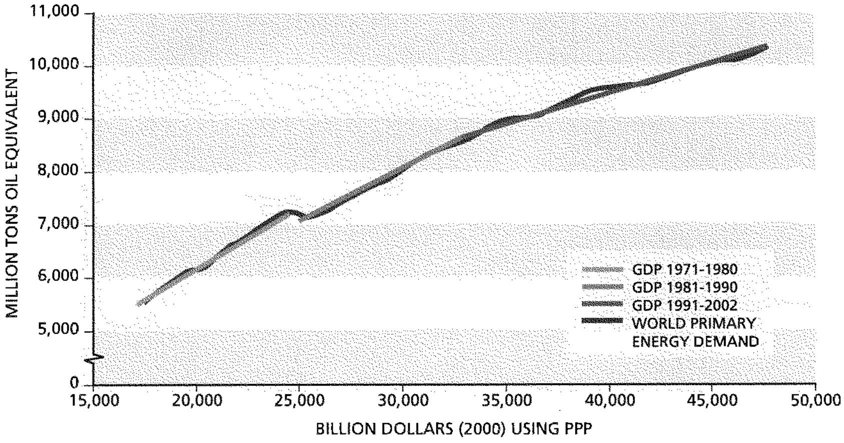
Aside from structural changes in the economy, the only way to reduce energy is through efficiency and conservation. For perspective, businesses and consumers have shown their unwillingness to make efficiency investments with returns of 10 percent. Two-year paybacks for businesses are often cited as the minimum for energy efficiency investments. Consumers often make decisions that imply returns of 50 percent or more. Lack of awareness and know-how are examples of barriers to investments in improved energy efficiency. It is likely that policy action would be required to encourage energy efficiency and conservation.



Source: NPC Natural Gas Study, 2003.

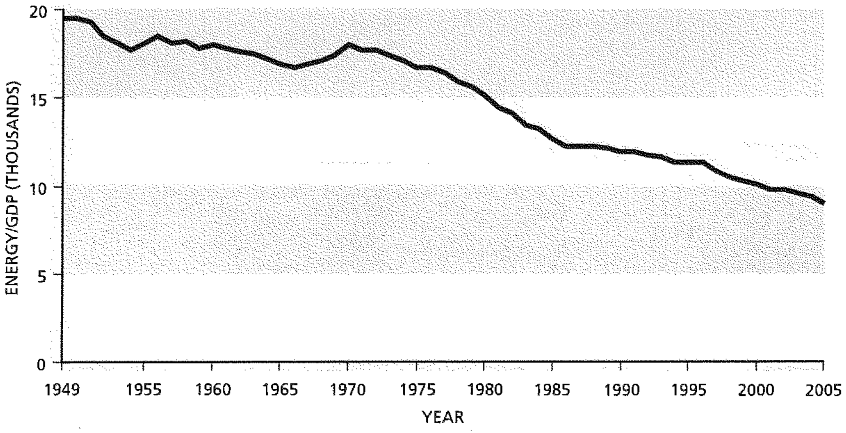
FIGURE 1-37. *Fuel Substitution Capability*

History suggests that energy-intensity reductions resulting from improved efficiency and structural change will be offset by increased demand for energy services unless policies are put in place to prevent such offsets. For example, technology that could have been used to increase vehicle miles per gallon in light duty vehicles has been used to increase vehicle horsepower and weight. Likewise, improvements in the efficiency (energy use per unit of service) of appliances and buildings have been offset by increased numbers of appliances and building sizes. While policies to promote improved energy efficiency may be more politically palatable than those that restrict demand



Source: IEA, *World Energy Outlook 2004.*

FIGURE 1-38. *World Primary Energy Demand and GDP, 1971-2002*



Source: EIA, *Annual Energy Review 2005.*

FIGURE 1-39. *U.S. Energy Intensity*

for energy services, those improving efficiency may not be sufficient to yield significant reductions from baseline projected energy demand.

2. Oil and natural gas demand are projected to increase rapidly in coming decades.

Global oil consumption is expected to increase by 40 percent from 2005 levels by 2030. Global natural gas demand is expected to increase by two-thirds by 2030; U.S. natural gas demand is expected to increase more slowly. The increase in demand for fossil fuels in non-OECD countries will be far more rapid than in OECD countries, both in absolute and percentage terms.

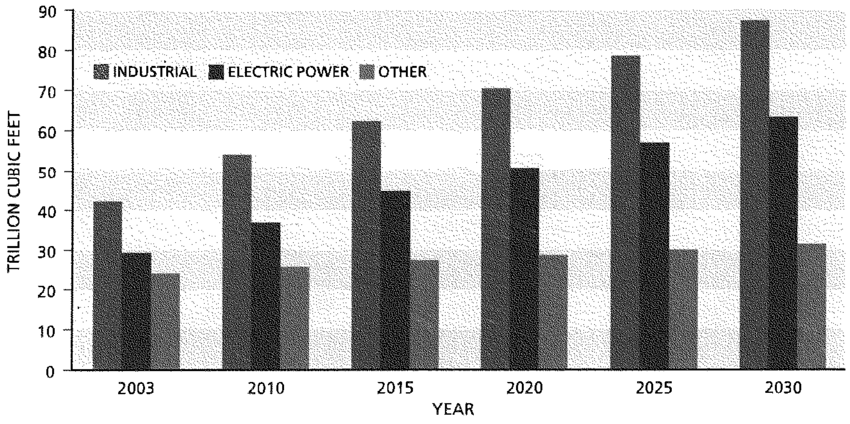
Transportation, industry, and "other" (mostly building heating) are the major sources of oil demand growth in the WEO 2006. Electric power sector demand is expected to decrease by about 1 million barrels per day. Oil demand growth in the transportation sector will exceed growth for all other uses combined. Projected industry and "other" category oil consumption are expected to increase by a large amount as well. These categories are expected to grow by 13 million barrels per day, which compares with a transportation oil consumption growth of around 22 million barrels per day.

Globally, electric generation and industry are the major sources of natural gas demand growth. Natural gas demand for electric generation and industry are expected to double. Natural gas use for building heating is also expected to increase (Figure 1-40).

Perhaps less obvious, electricity use in buildings will indirectly be a major source of natural gas demand growth. Appliances and other "buildings" related energy uses represent the largest component of electricity demand growth, and thus have major impact on the demand for natural gas. A large portion of electric generation growth is expected to be fueled by natural gas.

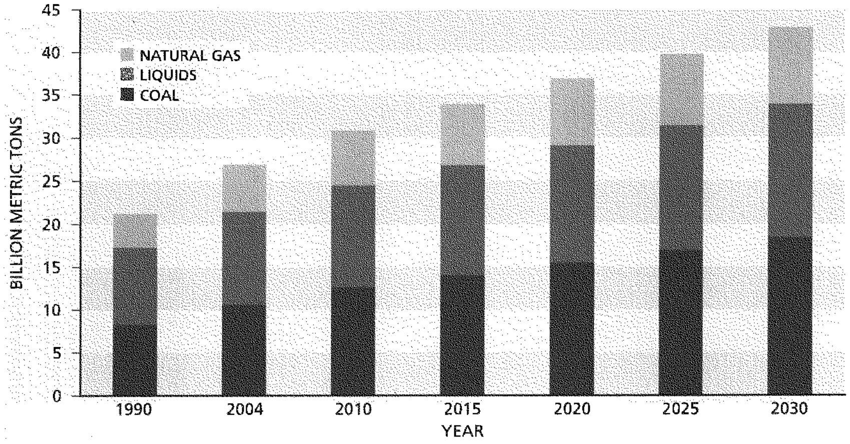
3. Carbon dioxide from fossil fuel combustion is growing.

Global CO_2 emissions are expected to increase by about half between 2004 and 2030, from around 27 billion tons to 40 billion tons (Figure 1-41). With slow growth in nuclear energy, and with renewable energy growing fast but starting from a low base, the carbon intensity of the global energy economy is projected to increase.



Sources: 2003: Derived from Energy Information Administration (EIA), *International Energy Annual 2003*; Projections: EIA, *International Energy Outlook 2006*.

FIGURE 1-40. *World Natural Gas Consumption by End-Use Sector, 2003-2030*



Source: EIA, *International Energy Outlook 2006.*

FIGURE 1-41. *World Energy-Related Carbon Dioxide Emissions by Fuel in the Reference Case*

The biggest contributor to global CO_2 emissions is coal, followed closely by oil and natural gas. Outside China, India, and the United States—all have large coal reserves—natural gas is expected to contribute significantly to the increase in CO_2 emissions.

The electric power sector is expected to be the dominant source of CO_2 emissions in the United States and globally—increasing from 40 percent in 2004 to 44 percent in 2030 worldwide (Table 1-13). The transportation sector, which is dominated by oil, will continue to be responsible for about one-fifth of CO_2 emissions. Yet much of the growth in electricity demand will come from residential and commercial buildings, which are already the largest single-sector source of CO_2 emissions when including the electricity generated that is used in buildings.

4. Keeping China in perspective.

Chinese energy use and GDP are projected to exceed those of the United States some time in the second half of the next decade. Chinese oil demand is projected to increase by twice as much as the U.S. oil demand through 2030 (Figure 1-42). Growth in China's oil demand is often cited as one of the major causes of higher global oil prices.

The fastest CO_2 emissions growth among major countries is occurring in China (Figure 1-43). Chinese emissions growth in 2000-2004 exceeded the rest of the world's combined growth due to increased use of coal and rapidly growing petroleum demand. Chinese CO_2 emissions are projected to pass U.S. emissions late in this decade.

While it is hard to overstate the ever-increasing importance of China in global energy markets and as a carbon emitter, it is important to put these numbers in perspective. The United States has had fast rates of energy and emissions growth for decades. As recently as the last decade (1990-2000), U.S. emissions growth was nearly as fast as China's is today. Even in 2030, China's projected oil demand will be less than the oil demand projected for the United States, both in per capita and absolute terms.

China has made major strides in reducing the carbon intensity of its economy (CO_2 per GDP). China's carbon intensity is roughly equal to that of the United States, and the intensities of both countries are projected to decrease at the same rate.

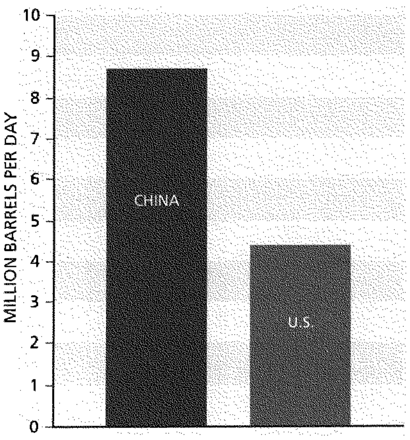
Nevertheless, while Chinese and U.S. carbon intensity will be similar during the next decade, per capita

	1990	2004	2010	2015	2030	2004-2030*
Power Generation	6,955	10,587	12,818	14,209	17,680	2.0%
Industry	4,474	4,742	5,679	6,213	7,255	1.6%
Transport	3,885	5,289	5,900	6,543	8,246	1.7%
Residential and Services†	3,353	3,297	3,573	3,815	4,298	1.0%
Other‡	1,796	2,165	2,396	2,552	2,942	1.2%
Total	20,463	26,079	30,367	33,333	40,420	1.7%

* Average Annual Growth Rate.
† Includes agriculture and public sector.
‡ Includes international marine bunkers, other transformation, and non-energy use.

TABLE 1-13. *World Energy-Related Carbon Dioxide Emissions by Sector in IEA's World Energy Outlook 2006 Reference Case (Million Metric Tons)*

carbon emissions will still be far lower in China. Likewise, on a per capita basis, U.S. oil demand is 10 times China's, and the United States will still consume 6 times as much per capita as China in 2030 (Figure 1-44).



Source: IEA, *World Energy Outlook 2006.*

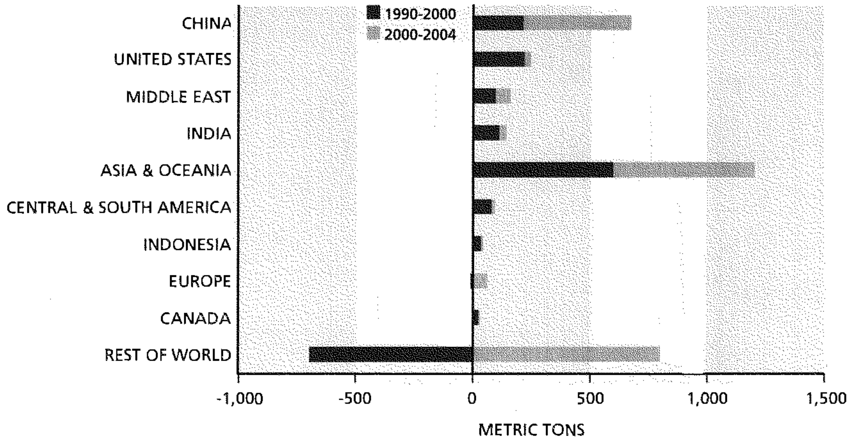
FIGURE 1-42. *Oil Demand Growth by 2030*

5. New technologies don't necessarily lead to reduced energy consumption.

There are any number of ways that information technologies could be used to reduce energy consumption, including telecommuting, dematerialization (i.e., the paperless office), and energy-efficient digital control systems in cars, buildings, and factories. The rapid penetration of information technologies in the economy has led some observers to predict accelerated reductions in U.S. and global energy intensity.

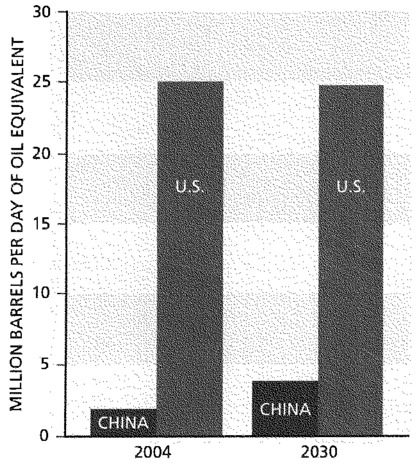
While the notion that technology development will lead to net reductions in energy use is appealing, is it proven, or even likely? Increased electric-plug loads associated with computers and other types of office equipment, and growing energy demand resulting from increased economic growth fueled by new information technologies, could induce a net increase in energy demand rather than a net decrease.

Based on various studies of information technology energy use, it can be estimated that information technology equipment currently uses about 210 terawatt-hours (210 trillion watt-hours), or about 5 percent of U.S. electricity consumption. This is almost as much electricity as could be saved by 2010 through efficiency measures with a cost of 10 cents or less per kilowatt-hour. In other words, the electricity consumed by information technologies in the United States, most introduced over the last decade, exceeds the



Source: EIA, *International Energy Annual 2004.*

FIGURE 1-43. *Regional Increase in Carbon Dioxide Emissions*



Source: IEA, *World Energy Outlook 2006.*

FIGURE 1-44. *Comparison of Oil Demand Per Capita — 2004 and 2030 Industry*

electricity-savings potential for refrigerators, washers, dryers, televisions, and the multitude of other electricity consuming appliances and equipment.

Technology advances make projecting energy-use trends particularly difficult. If excessive technological optimism causes an under estimation of future energy demand requirements, society could be forced to develop new energy sources hastily, at potentially great financial and environmental costs. Likewise, overly optimistic predictions that information technology (or any other technology) will reduce our reliance on fossil fuels might send the message that addressing energy challenges will not require any hard choices.

There are few historical precedents for new technologies actually reducing energy use (as opposed to just reducing energy intensity). New technologies often create new service demands at the same time that they improve the efficiency of existing service demands—the technology has the potential to reduce energy use, but gets called on for other purposes or allows (and in some cases even encourages) increased demand for new and additional energy services. For example, refrigerators are far more efficient (per cubic foot) than they were two decades ago, but more households have more than one refrigerator, and refrigerators have become bigger. Likewise, homes are better insulated and air conditioning and heating systems have become more efficient, but at the same time homes have grown in size. And cars, as discussed below, have become far more energy efficient, but that very efficiency has been offset by increased horsepower, size, and weight of vehicles.

In summary, care should be exercised when evaluating the future use of technology—information age or other—as a means of reducing future energy use.

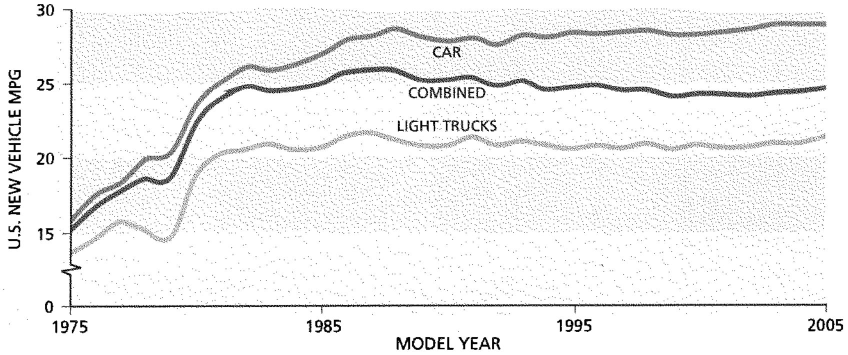
6. Large untapped potential for improved fuel economy in light duty vehicles.

Driven by rising incomes, global light duty vehicle (LDV) ownership rates are expected to increase from 100 vehicles per 1000 persons today to 170 in 2030. As a result, LDVs in use worldwide are expected to double, from 650 million in 2005 to 1.4 billion in 2030. Whereas U.S. and Japanese markets, for example, are expected to increase along with population, vehicle sales are expected to triple in non-OECD countries by 2030.

Vehicle fuel-use efficiency has increased. One recent study found that fuel-use efficiency (energy recovered per unit of fuel consumed) has increased by about 1 percent per year since 1987. This could have resulted in an increase of 0.2 miles per gallon per year. However, gains in efficiency have been offset by increases in vehicle weight, size, power, and accessories. If these factors had instead remained constant since 1987, average fuel economy would be 3-4 mpg higher for both cars and trucks than it is today (Figure 1-45).

Consequently, vehicle fuel economies (miles per gallon) in the United States have stagnated. Low fuel prices, combined with no increase in Corporate Average Fuel Economy (CAFE) standards, have led to U.S. light duty vehicle fleet-wide fuel economy that is essentially flat since the mid 1980s. At the same time, the structure of the CAFE standards allowed increased purchase of light trucks (SUVs, pick-ups, and minivans), which are subject to less-stringent fuel economy requirements. Cars still make up more than 60 percent of total vehicle miles traveled, but light trucks now account for more than half of the light duty vehicle sales in the United States, up from 20 percent in the 1976 to 53 percent in 2003. The period since the mid-1980s stands in stark contrast to the previous decade (1975-85), in which the fuel economy of America's light duty vehicles increased by two-thirds, driven by CAFE standards that increased annually.

There is a lot of uncertainty about business-as-usual trends in fuel economy. AEO 2006 projects that LDV fuel economy in the United States will increase 17 percent, from 24.9 mpg in 2003 to 29.2 mpg in 2030, in spite of an increase in horsepower of 29 percent. WEO 2006, however, projects an increase of just



Source: U.S. EPA, *Light-Duty Automotive Technology and Fuel Economy Trends: 1975-2003.*

FIGURE 1-45. *U.S. Car and Light-Truck Fuel Economy*

2.5 percent. Baseline expectations on improved fuel economy make a big difference in terms of how much energy savings we could expect from changes in CAFE standards or from other policies. Higher gasoline prices—if sustained—could result in the purchase of vehicles with better fuel economy, especially if fuel-economy improvements are available with little increase in price or reduced performance.

There are several technologies that could be used without short-changing vehicle performance, including continuously variable transmissions, engine supercharging and turbo charging, variable valve timing, cylinder deactivation, aerodynamic design, the integrated starter/generator, and low-resistance tires. In its 2002 report on fuel economy standards, the National Research Council found that a combination of various technologies could boost LDV fuel economy by one-third, and would be cost-effective for the consumer (would pay back over the life of the vehicles). With much higher gasoline prices, as seen in recent years, that savings potential is even greater. Note that all of these technological improvements could be used to improve other aspects of vehicle performance besides fuel economy.

Realizing such a fuel economy potential will likely require a range of policies to encourage improved fuel economy, including: increasing and/or reforming vehicle fuel economy standards, fuel taxes, and vehicle "feebates" (e.g., fee for low-fuel economy vehicles, rebate for high fuel economy vehicles).

7. Prices matter.

Rising prices, along with growing concerns about international energy security and global climate change have put energy in the news. Policymakers and business leaders want to know how much and when demand will respond to these high prices; and whether new policies and measures might stimulate the development of new energy resources and the more efficient use of existing energy resources.

Conventional wisdom, for example, suggests that there will be little quantity response to higher energy prices, at least in the short run. However, decades of econometric work suggests that over time consumers and businesses do adjust. Based on a meta-analysis by Carol Dahl (2006), which reviewed findings from 190 studies of elasticity conducted from 1990 through 2005, short-run price elasticity appears to range from around -0.1 to -0.3. In the long run, demand for various types of energy is roughly three times as responsive to price changes. However, demand is far more responsive to income than to price.

Past elasticities are not necessarily indicative of price responsiveness in the future. The magnitudes of all elasticities are influenced by changes in technology, consumer preferences, beliefs, and habits. It is entirely conceivable that a sustained period of high energy prices (for perhaps 5-10 years) could induce far greater percentage changes in the quantity of energy demand.

Elasticities could also be changed by policies. But given the relative importance of income compared to prices, if policies focus only on rising price signals without providing alternatives to current transportation and lifestyle patterns, consumers and businesses may view those policies as more punitive than productive.

8. Fuel-switching capabilities are declining in industry and increasing in transportation.

The ability to substitute fuels in a given sector affects how vulnerable that sector is to supply disruptions and associated price spikes. The ability to substitute fuels during a disruption lessens demand for the disrupted fuel, thereby reducing the size of the shortfall and the associated price spike. Lacking the ability to substitute fuels, prices need to rise to fairly high levels in times of shortage in order to reduce the activity that is generating the demand for fuel.

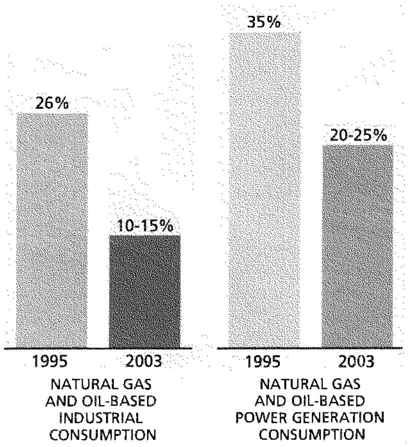
In the United States, the buildings sectors have very little ability (less than 5 percent) to switch fuel. Fuel-switching capabilities are higher, but falling, in the power and industrial sectors. Capability is low, but increasing, in the transportation sector.

The transportation sector is heavily reliant on petroleum and has little fuel substitution capability. About 5 million light duty vehicles in the United States have flexible fuel capability, representing about 2 percent of the total light duty fleet. By 2030, roughly one in ten light duty vehicle sales will have E-85 flex fuel (ethanol/gasoline) capability.

To make the widespread supply of E-85 economical will require more flex-fuel vehicles, substantial investments in the distribution system, and development of a second-generation feedstock that is not used for food (e.g., cellulosic ethanol). Even then, ethanol's ability to reduce price volatility for motor fuels will be limited unless there is spare ethanol production capacity. Meanwhile, increased reliance on ethanol could result in increased price volatility due to weather factors reducing crop size, transportation bottlenecks, high rail costs, and other local supply and demand factors.

Electric power generation appears to engage in significant short-term fuel switching, especially during times of high natural gas prices. This capability has declined over the last decade, from one-third of power generation gas boilers that were able to use residual fuel oil as a second fuel source in the mid-1990s to about one-quarter now (Figure 1-46). The reasons for the decline in fuel-switching capability include environmental restrictions, costs for additional storage of secondary fuels, and siting and related permitting complications that arise with multi-fuel generation facilities.

In the industrial sector, roughly one-fifth of the natural gas consumed can be switched to another fuel. Protection from highly volatile energy prices for residential and commercial consumers can be had indirectly via the other consuming sectors. To the extent that fuel flexibility and switching in the transportation, power, and industrial sectors mitigates price spikes and volatility, a spillover benefit accrues to the residential and commercial sectors.



Source: NPC Natural Gas Study, 2003.

FIGURE 1-46. Fuel Substitution Capability

RESIDENTIAL/COMMERCIAL EFFICIENCY ◆

Buildings are major consumers of oil and natural gas both nationally and globally, both directly and indirectly through the consumption of electricity generated from oil and natural gas. While most energy consumed in buildings is for traditional uses such as heating, cooling, and lighting, a growing portion is going to new electric devices, many of which were rare or even nonexistent just a few years ago. And, while significant efficiency improvements have been made in building shells, systems, and appliances, the potential energy savings have been partially offset by additional energy service demand requirements that have occurred as a result of increased home sizes as well as new and larger electric devices.

If all achievable, cost-effective energy-efficiency measures were deployed in residential and commercial buildings, anticipated energy use could be reduced by roughly 15-20 percent. The potential for cost-effective energy efficiency improvements depends heavily on the price of energy, consumer awareness and perceptions, and the relative efficiency of available products in the marketplace. These factors are determined in part by government policies.

The major barriers to energy-efficiency investments are low energy prices relative to incomes, due in part to externalities not being included in prices and government subsidies, split incentives (consumers of energy different from those selecting energy consuming facilities or paying for energy), and consumers' lack of information. To the extent that societal benefits from improved efficiency are recognized, government policies to promote energy efficiency are used. To reduce energy consumption significantly below levels associated with the current policy environment will require additional policy related improvements in energy efficiency. These policies should take into account the potential to increase energy-service consumption as a result of less energy consumption.

When energy losses in the generation and distribution of electricity are included, about 40 percent of U.S. energy is consumed in the residential and commercial buildings sectors. Current projections indicate that building energy use will increase by more than one third by 2030. Commercial building energy use is expected to increase by nearly half, due to continued growth in the service economy. Residential energy use is expected to grow at half that rate. The combined energy use growth in residential and commercial buildings is expected to represent about 45 percent of total primary energy growth.[4]

According to AEO 2007, buildings currently represent only about 6 percent of economy-wide petroleum consumption, a share projected to decline to about 4 percent by 2030. The natural gas story is quite different. Buildings consume 55 percent of natural gas and are expected to be responsible for about three quarters of the growth in natural gas consumption through 2030 (including gas used for electricity supplied to buildings). Commercial and residential buildings represent 52 percent and 25 percent, respectively, of overall projected natural gas consumption growth from 2005-2030.[5]

United States Residential/ Commercial Energy Use

The AEO Reference Case is an attempt by analysts at the EIA to predict efficiency improvements given projected energy prices and other factors influencing the penetration of various energy-saving technologies. Energy efficiency savings potential including additional policies, standards, behavioral changes, and technological breakthroughs far exceed the efficiency included in the AEO Reference Cases. Specific estimates of the exact magnitude of this potential vary widely.

Estimates of achievable, cost-effective reductions in building electricity use for commercial and residential buildings in the United States range from 7 to 40 percent below the Reference Case projections. The midrange appears to be around 20 percent for commercial buildings, and slightly less in residential buildings.

EIA (AEO 2007) estimates residential sector energy consumption (not just electricity consumption) would be 24 percent lower than in its Reference Case if "consumers purchase the most efficient products available at normal replacement intervals regardless of cost, and that new buildings are built to the most energy-efficient specifications available, starting in 2007." Energy-efficient building components would include, for example, solid-state lighting, condensing gas furnaces, and building envelope improvements such as high-efficiency windows and increased insulation.

Similarly, EIA (AEO 2007) estimates that commercial building energy consumption in 2030 would be 13 percent less than projected in its Reference Case if "only the most efficient technologies are chosen, regardless of cost, and that building shells in 2030 are 50 percent more efficient than projected in the Reference Case [including] the adoption of improved heat exchangers for space heating and cooling equipment, solid-state lighting, and more efficient compressors for commercial refrigeration." Table 1-14 lists efficiency improvements that could be achieved in several categories by 2030.

EIA efficiency-potential estimates are on the high end of the residential studies we examined, and on the low to mid range of the commercial estimates (see Figures 1-47 and 1-48). Note, however, that the EIA projections assume that cost is no concern, so inasmuch as the other efficiency potential studies include cost-effectiveness tests, we would expect the EIA estimates to be at the high end of the studies. Furthermore, the other studies are for the most part examining the potential for electricity savings, not energy savings overall.

According to the 2006 McKinsey Global Institute study of energy-efficiency potential, if all energy-efficiency measures with internal rates of return of 10 percent or better are implemented, U.S. residential energy demand could be reduced by 36 percent below its 2020 baseline and commercial energy use could be reduced by 19 percent. Using the same investment criteria, McKinsey estimates global residential building energy demand could be reduced by 15 percent below baseline and global commercial building energy demand could be reduced by 20 percent.[6]

As previously mentioned, most of the studies we examined estimated an efficiency potential of 10 to 20 percent in commercial buildings and 10 to 15 percent in residential buildings beyond business as usual, with the American Council for an Energy-Efficient Economy (ACEEE) studies estimating potentials as high as 35 percent for residential buildings in Florida and 40 percent for commercial buildings in Texas.

At the other extreme, the Electric Power Research Institute (EPRI) developed a supply curve for electric demand-side measures in 2010—including residential

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[4] Energy Information Administration, *Annual Energy Outlook 2007 with Projections to 2030,* Table 2, February 2007, http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_2.xls.

[5] Calculations based on data from *Annual Energy Outlook 2007,* Table 2.

[6] McKinsey Global Institute, *Productivity of Growing Global-Energy Demand: A Microeconomic Perspective,* November 2006.

Category	Appliance	Efficiency Improvement
Appliance	Refrigerators	22%
	Freezers	8%
Space heating	Electric heat pumps	10%
	Natural gas heat pumps	14%
	Geothermal heat pumps	5%
	Natural gas furnaces	6%
	Distillate furnaces	2%
Space cooling	Electric heat pumps	20%
	Natural gas heat pumps	10%
	Geothermal heat pumps	8%
	Central air conditioners	22%
	Room air conditioners	7%
Water heaters	Electric	3%
	Natural gas	6%
	Distillate fuel oil	0%
	Liquefied petroleum gases	6%
Building shell efficiency	Space heating – Pre 1998 homes	7%
Note: Index includes size of structure in the calculation	Space cooling – Pre 1998 homes	2%
	Space heating – New construction	2%
	Space cooling – New construction	2%

Source: Energy Information Administration, *Annual Energy Outlook 2007*, table 21, http://www.eia.doe.gov/oiaf/aeo/supplement/sup_rci.xls.

TABLE 1-14. *Residential Stock Efficiency Improvements, 2007-2030*

and commercial buildings, and industry.[7] According to the EPRI analysis, by 2010 the United States could reduce electricity use by about 150 terawatt-hours (3.9 percent of total U.S. electricity consumption) with measures costing less than 10 cents per kilowatt-hour and 210 terawatt-hours (5.5 percent) at 20 cents per kilowatt-hour or less. For reference, electricity consumption in 2005 totaled about 3,800 terawatt-hours[8] and the retail price of electricity in 2005 was 9.5 cents per kilowatt-hour for residential, 8.7 cents per kilowatt-hour for commercial, and 5.7 cents per kilowatt-hour for industrial.[9] At these prices, about 50 terawatt-hours (1.3 percent) of electric efficiency improvements could be achieved.

Buildings typically last decades if not centuries. Many of the features of buildings that affect their energy consumption—e.g., solar orientation, windows, tightness, and wall thickness—largely will go unchanged throughout the life of the building. Technologies and practices affecting these long-lived systems will be slow to penetrate the buildings stock and affect overall efficiency.

Building-energy codes typically target only new buildings and major rehabilitations, which is important

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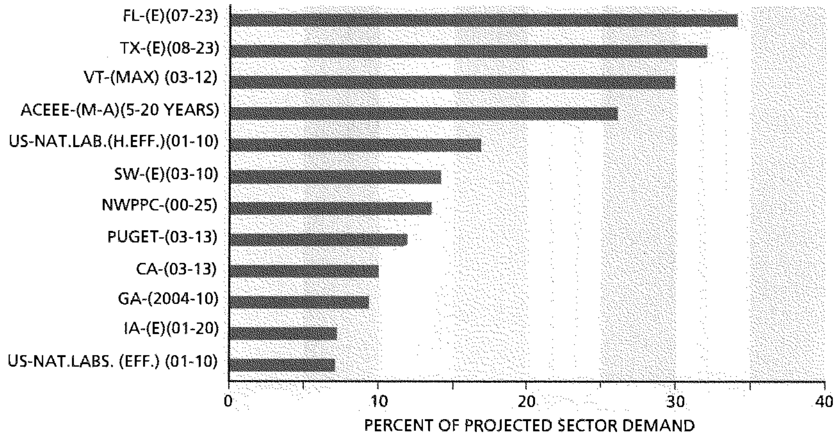
[7] Clark Gellings, Greg Wikler and Debyani Ghosh, "Assessment of U.S. Electric End-Use Energy Efficiency Potential," *The Electricity Journal*, November 2006, Vol. 19, Issue 9, Elsevier Inc, 2006, p.67.

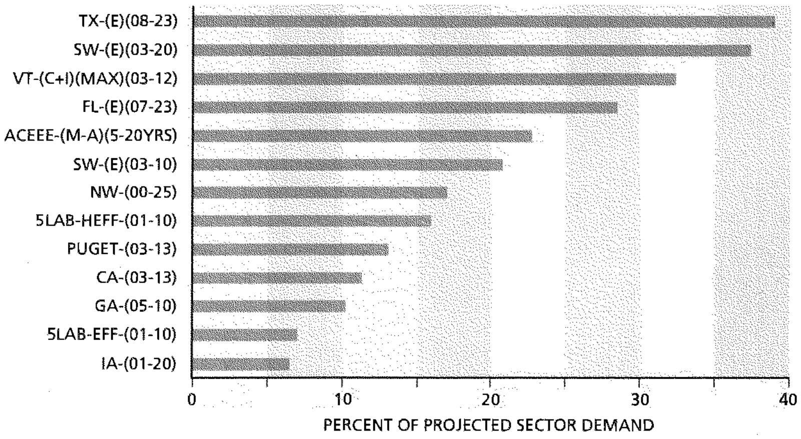
[8] Energy Information Administration, Electric Power Annual with data for 2005, November 2006, http://www.eia.doe.gov/cneaf/electricity/epa/epates2.html.

[9] Energy Information Administration, Electric Power Annual with data for 2005, November 2006, http://www.eia.doe.gov/cneaf/electricity/epa/epat7p4.html.



Source: Alliance to Save Energy, 2007.

FIGURE 1-47. *Achievable Potential for Electricity Savings in the Residential Sector (Various Studies)*



Source: Alliance to Save Energy, 2007.

FIGURE 1-48. *Achievable Potential for Electricity Savings in the Commercial Sector (Various Studies)*

because today's new buildings are tomorrow's existing buildings. New building codes and appliance standards can be bolstered to improve overall building energy use, but to significantly impact building energy use policies that induce significant savings in existing buildings are necessary. Appliance standards, labels and other measures target appliances and other equipment used in existing buildings.

Appliances, heating equipment, and air conditioning facilities are replaced as they wear out. Energy use can be addressed by standards for these applications as the equipment is replaced.

New buildings can be constructed to meet current "best practices" at the time of construction. Since buildings are usually constructed and used by different groups it is likely that standards would be needed to ensure construction that is economically thermally efficient for the areas in which construction takes place.

Translating Efficiency Into Reduced Energy Demand—"Consumption-Based Efficiency"

It is not always clear to what extent efficiency improvements are translated into actual reductions in energy demand. While the energy efficiency of homes has increased, so have home sizes. The average American home's floor area more than doubled between 1950 and 2000, as did floor area per capita; both square footage per home and per capita have increased by more than half just since the 1980s (see Figure 1-49).[10] Similarly, according to EIA's Residential Energy Consumption Survey (RECS), refrigerator energy use per household was roughly the same in 1993 and 2001, even though energy use per unit virtually halved during that time period.[11] While it is possible that second refrigerators would be commonplace regardless of unit efficiencies, it can at least be said that the demand for new energy services has increased as fast as efficiencies.

The demand for new energy services, such as second (and third) refrigerators and bigger homes, is driven by growing incomes, low energy prices, and to

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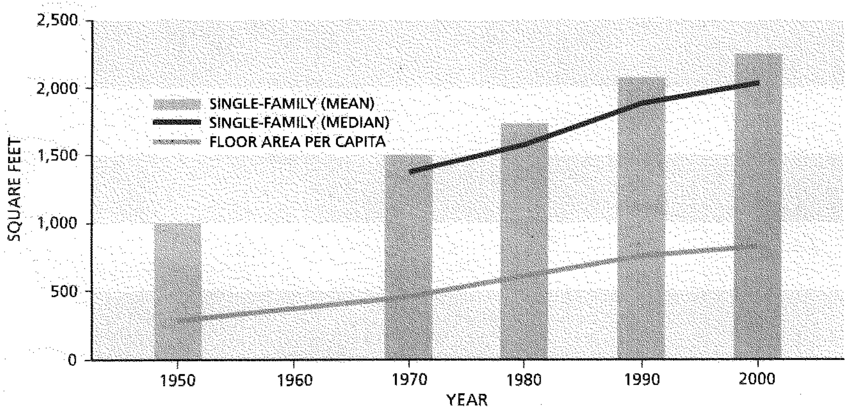
[10] National Association of Home Builders (NAHB), "Housing Facts: Figures and Trends 2003," 2003, Washington, DC.

[11] EIA, *Residential Energy Consumption Survey 1993*, 1993, Table 5.27, http://eia.doe.gov/pub/consumption/residential/rx93cet6.pdf, & *Residential Energy Consumption Survey 2001*, 2001, Table CE5-1c, http://www.eia.doe.gov/emeu/recs/recs2001/ce_pdf/appliances/ce5-1c_climate2001.pdf; estimated average household site electricity consumption for refrigerators was 5 million Btu in 2001 and 4.7 million Btu in 1993.



Source: Harris et al., *Don't Supersize Me! Toward a Policy of Consumption-Based Energy Efficiency*, Environmental Energy Technology Division, Lawrence Berkeley National Laboratory, 2006. Original data from National Association of Home Builders.

FIGURE 1-49. *U.S. House Size (Floor Area)*

some extent reduced operating costs due to improved efficiency. Some reductions in demand from energy-efficiency improvements are "taken back" in the form of increased demand for less-costly energy services. For example, efficiency improvements result in lower energy costs for refrigeration, which leads to increased demand for refrigerators. This "snapback" or rebound effect is estimated to be about 10 to 20 percent of the initial energy savings for most efficiency measures, although it varies depending on several factors, including end-use and elasticity of demand.[12]

Some energy-efficiency programs may even be contributing to—or at least not dampening—the increased demand for bigger appliances. The categorization of energy-using products for purposes of standards and labeling development may provide some perverse incentives to purchase products that are bigger, more powerful, or have more amenities. For example, ENERGY STAR label eligibility requirements for refrigerators vary by size—in some cases, the most efficient refrigerator in a larger class (which is therefore eligible for the ES label) may consume more energy than the least efficient in the smaller class (which is not eligible for the label). As a result, the ENERGY STAR label may inadvertently steer consumers toward "more efficient" refrigerators that are larger or have more amenities when the smaller refrigerator with fewer amenities and lower energy consumption might otherwise have been the choice.[13]

DEMAND STUDY POTENTIAL POLICY OPTIONS

From the work that was done by the Demand Task Group, the following list of potential policy actions was developed. The fundamentals supporting the list revolve around factors such as impact related to demand level, understanding of use, and effect on energy security. From this list, the overall study group developed three policies as study recommendations (see Policy Recommendations section below).

1. **Enhance international energy security framework.**

   China and India will account for a significant share of future growth in oil and gas demand. The United States should lead the enhancement of an international energy security framework, such as an expanded International Energy Agency, that includes China and India.

2. **U.S. leadership on environmental concerns.**

   If policy makers conclude that additional action to reduce carbon dioxide emissions is warranted, then the United States should take a leadership role to develop an effective global framework that involves all major emitters of carbon dioxide. Initiatives may be disjointed without U.S. leadership because some high growth developing countries are not likely to engage in such efforts unless developed countries, and especially the United States, take a clear leadership role.

3. **Areas should be identified where market solutions to support energy efficiency may not be fully effective.**

   Policy makers should consider policies that encourage energy-efficiency improvements, including metrics to measure progress.

4. **Raise vehicle fuel efficiency at the maximum rate consistent with available and economic technology.**

   Vehicle fuel efficiency standards should be raised. The interests of all concerned parties should be considered when establishing new efficiency standards. Significant gains in efficiency have occurred in the past. The average fuel efficiency of new cars doubled from 1974 to 1985. The Transportation Efficiency Subgroup analysis said "technologies exist, or are expected to be developed, that have the potential to reduce fuel consumption by 50 percent relative to 2005."

5. **The federal government should a) encourage states to implement more aggressive energy efficient building codes and b) update appliance standards.**

   Building codes and appliance standards should be updated to reflect currently available technology. New, up-to-date standards should be enforced. Options should be developed for enhancing current incentives to retrofit existing structures for improved energy efficiency.

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[12] Resources for the Future, "Retrospective Examinations of Demand-Side Energy Efficiency Policies," Discussion Paper, 2006.

[13] Jeffrey Harris, Rick Diamond, Maithili Iyer, Chris Payne and Carl Blumstein, *Don't Supersize Me! Toward a Policy of Consumption-Based Energy Efficiency*, Environmental Energy Technologies Division, LBNL, 2006 ACEEE Summer Study on Energy Efficiency, p. 7-108.

6. **Encourage greater efficiency in the industrial sector.**

   Foster research, development, demonstration, and deployment of energy efficiency technologies and practices in the industrial sector. The U.S. industrial sector consumes one-third of the energy used in the United States. Technologies exist that could save 15 percent of this energy, but only one-third of this is currently economic. Further research and development is required to implement the remaining potential gain in efficiency. Areas of opportunity include waste heat recovery and boiler/steam efficiency. Make permanent the research and development tax credit is an option to increase industrial energy efficiency.

7. **Visible and transparent carbon dioxide cost.**

   If policy makers conclude that additional action to limit carbon dioxide emissions is warranted, then a mechanism should be developed that establishes a cost for emitting carbon dioxide. The mechanism should be economy-wide, visible, transparent, applicable to all fuels, and durable for the long-term. By establishing a cost (or price), companies will be better positioned to determine how to restrain carbon dioxide emissions. A carbon dioxide cap-and-trade system or a carbon dioxide tax are two possibilities that could reduce emissions and establish a carbon dioxide cost.

8. **The U.S. manufacturing industry and national security will be enhanced through a diverse range of fuels to generate power.**

   Fuel choice for power generation should be fostered to avoid increasing dependence on a single fuel. Reference projections indicate that the United States will be increasingly reliant on LNG imports to satisfy domestic natural gas demand. There are several potential drivers that could result in even higher domestic natural gas demand—e.g., escalating construction costs and greenhouse gas considerations, both of which favor natural gas over coal for new electrical power generation. Relying too heavily on natural gas for power generation could displace energy intensive manufacturing from the United States.

9. **Improve energy data collection.**

   Energy data collection efforts around the world should be expanded to provide data in a consistent and timely fashion. India and China should be encouraged to participate in world energy data collection.

10. **Improve energy modeling.**

    Development and use of economic activity feedback projection techniques should be encouraged to aid in evaluation of critical policies such as carbon constraint.

POLICY RECOMMENDATIONS

Improve Vehicle Fuel Economy

Nearly half of the 21 million barrels of oil products that the United States consumes each day is gasoline used for cars and light trucks. The Reference Case in AEO 2007 projects that gasoline consumption will increase by an average of 1.3 percent per year, totaling an increase of 3 million barrels per day between 2005 and 2030.

The CAFE standards have been the primary policy used to promote improved car and light-truck fuel economy in the United States over the last three decades. The original standards created one economy requirement for cars, and another less stringent one for light trucks to avoid penalizing users of work trucks. At the time, light-truck sales were about one-quarter of car sales. Since then, sport utility vehicles and minivans classified as light trucks have increased their share of the market. Now, these light-truck sales exceed car sales, and the increase at the lower truck fuel economy standard has limited overall fuel economy improvement.

Cars and trucks sold today are more technically efficient than those sold two decades ago. However, the fuel economy improvements that could have been gained from this technology over the last two decades have been used to increase vehicle weight, horsepower, and to add amenities. Consequently, car and truck fuel economy levels have been about flat for two decades, as previously shown in Figure 1-45.

Based on a detailed review of technological potential, a doubling of fuel economy of new cars and light trucks by 2030 is possible through the use of existing and anticipated technologies, assuming vehicle performance and other attributes remain the same as today.[14] This economy improvement will entail higher vehicle cost. The 4 percent annual gain in CAFE standards starting in 2010 that President George W. Bush suggested in his 2007 State of the Union speech is not inconsistent with a potential doubling of fuel economy for new light duty vehicles by 2030. Depending upon how quickly new vehicle improvements are incorporated in the on-road light duty vehicle fleet, U.S. oil demand would be reduced by about 3-5 million barrels per day in 2030.[15] Additional fuel economy improvements would be possible by reducing vehicle weight, horsepower, and amenities, or by developing more expensive, step-out technologies.

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[14] See in this report, "Transportation Efficiency" section of Chapter 3, Technology. The extent to which technologies translate into reductions in fuel consumption depends on several factors, including costs, consumer preferences, availability, deployment, and timing.

Recommendation

The NPC makes the following recommendations to increase vehicle fuel economy:

- **Improve car and light-truck fuel economy standards at the maximum rate possible by applying economic, available technology.**
  - **Update the standards on a regular basis.**
  - **Avoid further erosion of fuel economy standards resulting from increased sales of light trucks, or, alternatively, adjust light-truck standards to reflect changes in relative light-truck and car market shares.**

Potential Effect: 3-5 million barrels of oil per day in the United States from the increased base in 2030.

Reduce Energy Consumption in the Residential and Commercial Sectors

Forty percent of U.S. energy is consumed in the residential and commercial sectors, including the energy lost while generating and distributing the electricity used. The EIA projects that U.S. residential and commercial energy use will increase almost one-third by 2030.

Significant efficiency improvements have been made in buildings over the last several decades. Improvement areas include the building structure itself; heating, cooling, and lighting systems; and appliances. However, these improvements have been partly offset by increased building sizes and by use of larger and multiple appliances. Cost-effective energy efficiency building technologies have outpaced current U.S. federal, state, and local policies. If applied, currently available efficiency technology would reduce energy use an additional 15-20 percent.[16]

Buildings typically last for decades. Many of the features of buildings that affect their energy consumption, such as wall thickness, insulation, structural tightness, and windows, will go largely unchanged throughout the life of the building. Technologies and practices affecting these long-lived systems will be slow to penetrate the building stock and affect their overall efficiency, making it important to implement policies early to achieve significant long-term savings.

Major barriers to energy efficiency investments include initial costs, insufficient energy price signals, split incentives (where the consumer is different from the facility provider), and individual consumer's limited information. To reduce energy consumption significantly below the projected baseline will require policy-driven improvements in energy efficiency.

Building Energy Codes

Building energy codes have proved to be a significant policy tool to encourage increased energy efficiency in new buildings, and in buildings undergoing major renovations. Building codes are administered by the 50 states and by thousands of local authorities. To help state and local governments, national model energy codes are developed and updated every few years. Under federal law, states are not obligated to impose energy codes for buildings, although at least 41 states have adopted some form of building energy code.

Adopting a building code does not guarantee energy savings. Code enforcement and compliance are also essential. Some jurisdictions have reported that one-third or more of new buildings do not comply with

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[15] The potential fuel savings of 3 to 5 million barrels per day in 2030 is relative to a scenario where current fuel economy standards remain unchanged through 2030.

[16] Baseline projections taken from Energy Information Administration, *Annual Energy Outlook 2007 with Projections to 2030*, Table 2, February 2007, http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_2.xls; savings estimates taken from several studies including *Building on Success, Policies to Reduce Energy Waste in Buildings*, Joe Loper, Lowell Ungar, David Weitz and Harry Misuriello – Alliance to Save Energy, July 2005. "Achievable" used here means that the measures are currently available and the savings can be realized with a reasonable level of effort and with acceptable reductions, if any, in perceived amenity value.

For additional discussion, see the *National Action Plan for Energy Efficiency*, which is available at: http://www.epa.gov/cleanrgy/actionplan/eeactionplan.htm critical energy code requirements for windows and air conditioning equipment, which are among the easiest energy saving features to verify.[17]

Building energy codes typically target only new buildings and major renovations. Additional policies are needed to encourage incremental, significant savings in existing buildings.

Appliance and Equipment Standards

Standards for appliances and other equipment are major policy measures that reduce energy use in existing buildings. These products may not consume much energy individually, but collectively they represent a significant portion of the nation's energy use.[18]

Energy efficiency standards currently do not apply to many increasingly common products, including those based on expanded digital technologies. Product coverage must be continuously evaluated and expanded when appropriate to assure inclusion of all significant energy consuming devices. In addition, industry and other stakeholders have negotiated standards for other products, such as residential furnaces and boilers. Implementing and enforcing expanded and strengthened standards would reduce energy consumption below the levels that will result from current Department of Energy requirements.[19]

Residential and commercial efficiency gains are partially consumed by increased use of the services and products that become more efficient. For example, U.S. house sizes have increased steadily over the years, offsetting much of the energy efficiency improvements that would have resulted had house sizes not swelled. Similarly, household refrigerators have increased in number and size, consuming much of the reduced energy use per refrigerator gained by efficiency standards. Energy efficiency programs should consider steps to avoid increasing the demand for energy services.

Recommendation

The NPC makes the following recommendations to improve efficiency in the residential and commercial sectors:

- Encourage states to implement and enforce more aggressive energy efficiency building codes, updated on a regular basis.
- Establish appliance standards for new products.
- Update federal appliance standards on a regular basis.

Potential Effect: 7-9 quadrillion Btu per year by 2030 in the United States, including 2-3 quadrillion Btu per year of natural gas (5-8 billion cubic feet per day), 4-5 quadrillion Btu per year of coal, and ~1 quadrillion Btu per year (0.5 million barrels per day) of oil.

Increase Industrial Sector Efficiency

The industrial sector consumes about one-third of U.S. energy, and contributes to a large share of the projected growth in both oil and natural gas use globally and in the United States. Worldwide, industrial demand for natural gas is expected to double by 2030. Worldwide, industrial sector demand for oil is expected to increase by 5 million barrels per day, or 15 percent of total oil demand growth through 2030.

The industrial sector is a price-responsive energy consumer. U.S. energy-intensive industries and manufacturers rely on internationally competitive energy supplies to remain globally competitive. In recent years, U.S. natural gas prices have risen faster than those in the rest of the world. As a result, U.S. energy-intensive manufacturers using natural gas as a fuel or feedstock have responded by increasing the efficiency of their operations and/or by shifting more of their operations to lower energy cost regions outside the United States.

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[17] From *Building on Success, Policies to Reduce Energy Waste in Buildings*, Joe Loper, Lowell Ungar, David Weitz and Harry Misuriello – Alliance to Save Energy, July 2005, pp. 18-19. For a compilation of compliance studies, see U.S. Department of Energy, *Baseline Studies*, on web site (http://www.energycodes.gov/implement/baseline_studies.stm). Arkansas reports 36 of 100 homes in the study sample did not meet the HVAC requirements of the state energy code.

[18] From *Building on Success, Policies to Reduce Energy Waste in Buildings*, Joe Loper, Lowell Ungar, David Weitz and Harry Misuriello – Alliance to Save Energy, July 2005, p. 24

[19] For additional savings potential see Steven Nadel, Andrew deLaski, Maggie Eldridge, & Jim Kleisch, *Leading the Way: Continued Opportunities for New State Appliance and Equipment Efficiency Standards*, March 2006, http://www.standardsasap.org/a062.pdf.

Across the industrial sector, there are opportunities to increase energy efficiency by about 15 percent.[20] Areas for energy savings include waste-heat recovery, separation processes, and combined heat and power.[21] While 40 percent of that opportunity could be implemented now, further research, development, demonstration, and deployment are required before the remaining savings can be achieved. Providing programs that encourage deployment of energy efficiency technologies and practices will hasten their implementation. Making the federal research and development tax credit permanent is one way to encourage private investment in these areas. However, a lack of technically trained workers can impede the implementation of efficiency projects while the uncertainty from price volatility can make justifying those projects difficult.

Recommendation

The NPC makes the following recommendations to improve efficiency in the industrial sector:

- The Department of Energy should conduct and promote research, development, demonstration, and deployment of industrial energy efficiency technologies and best practices.
- The research and development tax credit should be permanently extended to spur private research and development investments.

Potential Effect: 4-7 quadrillion Btu per year by 2030 in the United States, about equal parts coal, gas, and oil.

Generation of electricity uses a significant amount of energy. In the United States, about 30 percent of primary energy is used by the electric power generating sector. Only modest generation efficiency improvements appear economically feasible in existing plants (2 to 6 percent), as efficiency improvements are incorporated during routine maintenance. The major potential for efficiency improvement comes when existing generation plants are replaced with facilities using updated technology and designs. Retirement of existing facilities and selection of replacement technology and design is driven by economics affected by fuel cost, plant reliability, and electricity dispatching considerations.

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[20] From the *Chemical Bandwidth Study*, DOE, 2004; *Energy Bandwidth for Petroleum Refining Processes*, DOE, 2006; *Pulp and Paper Industry Energy Bandwidth Study*, AIChE, 2006.

See also *Curbing Global Energy Demand Growth: The Energy Productivity Opportunity*, McKinsey Global Institute, May 2007.

[21] "Combined heat and power" refers to using the excess heat from generating electricity to meet processing or building heat needs. This combination is frequently called "cogeneration" and results in a substantial increase in efficiency versus generating electricity and heat separately.

Chapter 2
ENERGY SUPPLY

Abstract

World energy resources are plentiful, but accumulating risks threaten continued expansion of oil and natural gas production from conventional sources relied on historically. To mitigate these risks, expansion of all economic energy sources will be required, including coal, nuclear, renewables, and unconventional oil and natural gas. Each energy source faces significant challenges, including technical, environmental, political, or economic hurdles, and each imposes infrastructure requirements for development and delivery.

This chapter examines endowment, resource, and production dynamics; describes the historical and projected energy mix; analyzes diverse public and aggregated proprietary data sources; and considers options for energy infrastructure and delivery.

The outline of the Energy Supply chapter is as follows:

- Supply Summary
- Prospects for Energy Supply
- Analysis of Energy Outlooks
  - Oil and Other Liquids
  - Natural Gas
  - Coal
  - Biomass
  - Non-Bio Alternative Energy Sources
  - Energy Conversion and Delivery Infrastructure
- Access to Resources.

A set of detailed studies on specific supply-related topics supports the analysis in this chapter. These topic papers are included on the CD distributed with this report (a list of all the topic papers can be found in Appendix E). The data used for analyzing energy outlooks are included in the Data Warehouse section of the CD.

SUPPLY SUMMARY

The question of future energy supplies is significant, controversial, and extends beyond oil and gas. Energy supply is a complex system that includes several basic components: (1) the natural endowment or physical store of a particular resource; (2) production or conversion of the resource to usable form; and (3) delivery of products to consumers. The components function within a larger and changing economic, geopolitical, and technical context. The study takes a comprehensive view that includes each of these elements for fossil hydrocarbons and other energy sources such as biomass, nuclear, and non-bio renewables.

Data Sources

The study considered a diverse set of data that represents the range of opinion about energy supply. These data were collected in the NPC Survey of Global Energy Supply/Demand Outlooks ("NPC Survey of Outlooks"). Figure 2-1 shows the sources of supply forecasts and

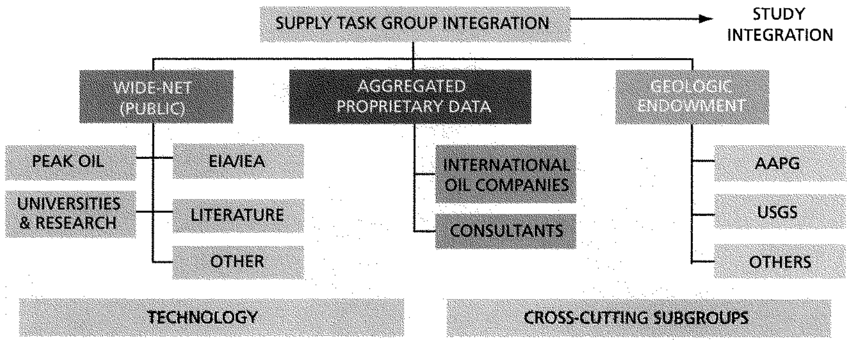


FIGURE 2-1. *Supply Data Sources*

data about the underlying resource base. The comprehensiveness of the data is unique to this study and established an objective basis for the findings.

The data were classified into categories that included quantitative forecasts as well as reports and opinion papers:

- *Public data* are freely available from agencies such as the U.S. Energy Information Administration (EIA) and the International Energy Agency (IEA); academic and research institutions; interest groups; open literature; and foreign governments.
- *Proprietary data* were made available to the study, anonymously and with strict safeguards, by private businesses such as energy companies and industry consultancies.
- *Endowment data* represent expert technical opinion about the physical resource base for hydrocarbons and other sources of energy.

Source data ranged from integrated supply-demand projections through studies of specific elements of the energy system such as biomass and transportation infrastructure. See the Methodology chapter of this report for full details about the techniques used in data collection and analysis.

Resource Endowment

Endowment and recoverable resources are fundamental concepts in any discussion of energy supply. *Endowment* refers to the earth's physical store of potential energy sources: tons of coal, cubic feet of natural gas, barrels of oil, etc. The endowment of fossil hydrocarbons is fixed: it can be depleted but not replenished. *Recoverable resources* are a subset of the hydrocarbon endowment—the portion that can be viably produced and converted to fuel and power.

The natural endowment is the foundation of all supply projections. Although there are many estimates for future producible reserves and production, these are often based on the same resource estimates, principally data compiled by the United States Geological Survey (USGS). Other estimates are made by energy companies and non-U.S. governmental agencies. However, public and proprietary assessments are not integrated with each other and may use different methodologies. The wide range of assessments creates uncertainty for policy makers.

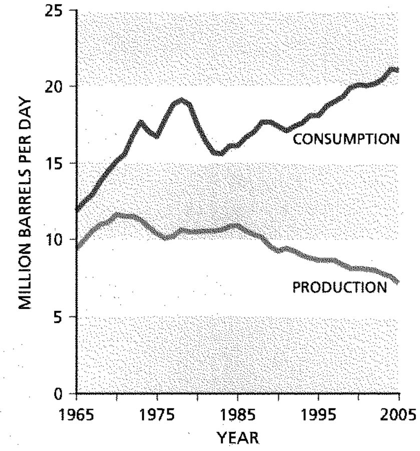
Current endowment and resource assessments for oil, gas, and coal indicate very large in-place volumes and resource potential, several times the cumulative produced volumes and current reserve estimates. Renewable resources such as biomass, wind, and solar power add additional potential. However, physical, technical, commercial and other constraints make only a fraction of any endowment available for extraction. The key consideration for all energy sources is converting the resource endowment to economically and environmentally viable production and delivery.

Resources to Production

The United States is the world's largest cumulative oil producer and remains the third-largest daily producer after Saudi Arabia and Russia. However, Figure 2-2 shows that U.S. oil production has declined steadily over the past 40 years. Demand for oil (and natural gas) has grown at the same time, creating a gap with domestic production that is filled by imports. Any continuing production decline for domestic oil will widen the projected gap between supply and consumption over the next 25 years and beyond. Accumulating geological, geopolitical, investment, and infrastructure risks to global oil and natural gas supply may compound the gap.

Supply forecasts are wide ranging and reflect uncertainty at least partly based on recent difficulty in increasing oil production. Forecast worldwide liquids production in 2030 ranges from less than 80 million to 120 million barrels per day, compared with current daily production of approximately 84 million barrels. The capacity of the oil resource base to sustain growing production rates is uncertain. Several outlooks indicate that increasing oil production may become a significant challenge as early as 2015. The uncertainty is based on (1) the rate and timing at which significant quantities of unconventional oil enter the supply mix; (2) industry's ability to overcome increasing risks to supply. Figure 2-3 illustrates potential sources of total liquids supply as depicted in the IEA *World Energy Outlook 2004* (WEO 2004). This figure is an illustrative example of the various components that make up total liquids supply, although the timing and combination of the components may vary.

Public and proprietary supply projections are based on assumptions about underlying factors such as economic growth, energy prices, and resulting demand; carbon constraints; technology; and maximum production volumes and timing. The EIA's low economic growth case, for example, forecasts 50 percent growth in total global energy supply by 2030, while its high economic growth case forecasts 90 percent growth. The EIA, IEA, and consultant reference and high-demand cases result in the highest projected global oil production levels. In contrast, the production maximum (or peak oil) and carbon-constrained cases project the lowest estimates of global oil production. International oil company (IOC) outlooks are considerably higher than the lowest supply cases, but lower than the EIA and IEA Reference Cases. The distribution of supply outlooks itself raises uncertainties and reflects different assessment of the risks involved in finding, producing, and delivering energy.

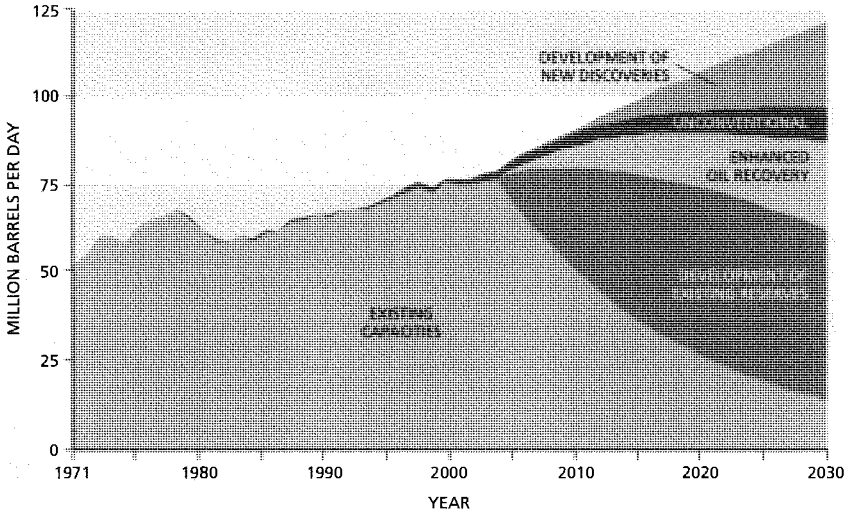


Source: *BP Statistical Review of World Energy 2006.*

FIGURE 2-2. *U.S. Oil Production and Consumption*

The USGS mean assessment indicates that natural gas resources are at least adequate for the increased production anticipated over the study period. However, the increased production will require replacing approximately 50 percent of the existing global natural gas reserve base by 2030.

Coal is a unique energy resource for the United States. Given its vast resource base—by many estimates, the world's largest—and major contribution to electricity generation today, coal is likely to remain a fundamental, long-term component of U.S. energy supply. Many studies forecast growth in coal use for power, plus additional growth through direct conversion of coal to liquids to diversify the fuel supply. However, coal combustion is also the largest source of carbon dioxide emissions from energy production. Adding coal-to-liquids production at scale, as with conversion of most heavy unconventional hydrocarbons, would generate large additional volumes of carbon dioxide. Addressing carbon capture at scale



Source: IEA, *World Energy Outlook 2004.*

FIGURE 2-3. *Illustrative Total Liquids Supply*

is therefore a prerequisite for retaining coal as a viable and critical part of the energy supply system.

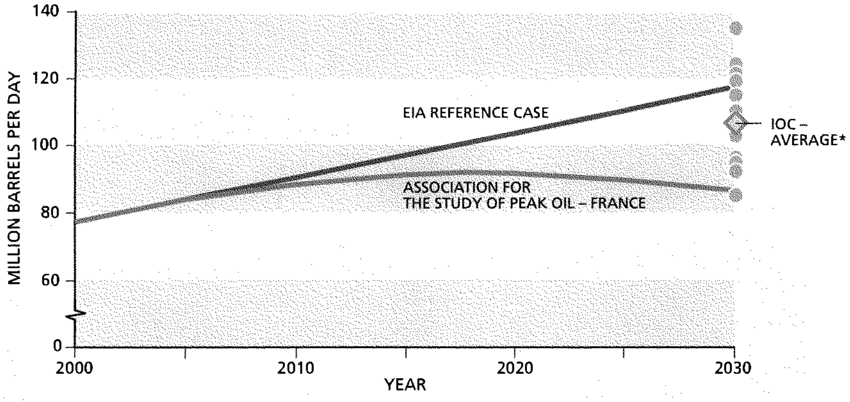
Understanding the Range of Production Forecasts

This study examined a comprehensive range of global oil production forecasts including integrated supply/demand studies from EIA and IEA (unless otherwise noted, all EIA data referred to in this chapter are from *International Energy Outlook 2006* and IEA data are from *World Energy Outlook 2006*); publicly available projections from a diverse range of other sources; and a unique set of aggregated proprietary forecasts from IOCs and energy consulting groups. The diversity of this range of projections is shown in Figure 2-4, which highlights the EIA reference, the Association for the Study of Peak Oil (ASPO) – France, and the average of the IOC forecasts for 2030. The distribution of production forecasts highlights the effect of assigning different levels of risk and uncertainty to both resource and above-ground factors. This distribution of outcomes, along with evaluation of assessments of the total resource base, indicates that the key consideration for energy supplies is not endowment but "producibility." Over the next 25 years, risks above ground—geopolitical, technical, and infrastructure—are more likely to affect oil and natural gas production rates than are limitations of the below-ground endowment. The range of outcomes emphasizes the need for proactive strategies to manage the accumulating risks to liquids delivery in 2030.

Explanations for the variance in projections for both conventional oil and natural gas production are widely discussed as part of the "peak oil" debate. As a result, this study sees the need for a new assessment of the global oil and natural gas endowment and resources to provide more current data for the continuing debate.

Diversification

Growing U.S. energy demand requires diversified energy sources that are economically and environmentally sustainable at commercial scale. Coal and



* Average of aggregated proprietary forecasts from international oil companies (IOC) responding to the NPC survey. See Analysis of Energy Outlooks, Global Total Liquids Production, later in this chapter for identification of other aggregations and outlooks shown here.
Source: EIA, *International Energy Outlook 2006*, and the NPC Survey of Outlooks.

FIGURE 2-4. *Global Total Liquids Forecasts*

nuclear power already play a significant role. Most forecasts expect them to at least retain their relative share of the supply mix. Many forecasts project significant growth for unconventional hydrocarbons, including very heavy oil and bitumen expansion from Canadian oil sands. At a more challenging technical and economic level, many forecasts also predict growing contributions from large-scale conversion of coal to liquids and the eventual development of vast U.S. oil shale resources. All unconventional hydrocarbons face the critical issue of their significant carbon footprint at large-scale implementation.

Biomass and other renewables are playing a growing role as options for transportation fuel or power generation, with high year-to-year growth rates. Biomass includes wood, cultivated crops, or naturally growing vegetation that potentially can be converted to energy sources at commercial scale. First-generation conversion of biomass to fuels is based on corn, sugarcane, soybeans, or other crops that are also food sources. Technically and economically successful, second-generation conversion of plant waste or fuel crops would allow non-food vegetation to be used as feedstock. As with all energy sources, technical, logistical, and market requirements will need to be met to achieve significant scale.

Energy projections generally show a continuing role for nuclear energy, notwithstanding unique concerns about safety, security, and waste disposal. In a carbon-constrained environment, nuclear energy may become a much larger part of the energy mix. However, the U.S. technical and industrial capability needed to maintain nuclear energy as an option is at risk.

Key Findings

Oil, gas, and coal—the fossil hydrocarbons—are by far the largest sources of energy in industrial economies. While alternative energy sources, particularly biomass and other renewables, are likely to increasingly contribute to total energy supply, hydrocarbons are projected to dominate through at least 2030.

The prospects for hydrocarbon supply are complex. They involve a growing set of global uncertainties ranging from production capabilities through environmental constraints, infrastructure requirements, and geopolitical alignments. Concentration of remaining oil and gas resources in a few countries, for example, challenges whether business-as-usual cases represent the most likely course of events during the period to 2030.

Economically disruptive supply shortfalls of regional, if not global, scale are more likely to occur during the outlook period than in the past. Increased demand will amplify the effects of any short-term events, which are likely to result in stronger reactions than in the past to protect national interests. The new dynamics may indicate a transition from a demand-driven to a supply-constrained system.

While uncertainties have always typified the energy business, the risks to supply are accumulating and converging in novel ways:

- Resource nationalism, bilateral trade agreements, or protectionist policies may remove resources from the market and make them unavailable for general world supply.
- Hydrocarbon resources are becoming more difficult to access and challenging to produce.
- Technology requirements are increasingly complex and demanding.
- Costs of developing and delivering energy are escalating.
- Demands on current and anticipated infrastructure are heavy and growing.
- Human resources may not be adequate to meet projected growth requirements.
- Environmental constraints on energy supply are evolving and indeterminate.

These risks and uncertainties are the basis for understanding supply prospects over the next several decades.

The energy supply system has taken more than a century to build, requiring huge sustained investment in technology, infrastructure, and other elements of the system. Given the global scale of energy supply, its significance, and the time required for substantive changes, inaction is not an option. Isolated actions are not a solution. The study's recommendations address the supply issue as a whole and contribute to building a secure, sustainable energy portfolio.

PROSPECTS FOR ENERGY SUPPLY

Energy Endowment and Recoverable Resources

Endowment and recoverable resource are fundamental concepts in any complete discussion of energy supplies. This section defines these and other concepts used in supply forecasts. For detailed review and discussion of endowment and recoverable resources, see the Endowment and Biomass Topic Papers on the CD included with this report.

The *endowment* of fossil energy sources refers to the earth's physical store of non-renewable hydrocarbons: tons of coal, cubic feet of natural gas, barrels of oil, etc. The total endowment of fossil hydrocarbons is fixed. Some fraction can be developed and depleted, but the endowment cannot be replenished in less than geologic time frames. Renewable resources, such as biomass, represent an additional potential energy endowment, which, in principle, is continuously replenished. *Recoverable resources* are the subset of the total endowment that can be ultimately produced and converted into fuel and power.

Why We Do Endowment Assessments

Hydrocarbon resource assessments fill a variety of needs for consumers, policy makers, land and resource managers, investors, regulators, industry planners, and others involved in energy policy and decision making.

Individual governments use resource assessments to exercise stewardship, estimate future revenues, and establish energy, fiscal, and national security policy. Energy industries and the investment community use resource estimates to establish corporate strategy and make investment decisions. Other interested parties use the estimates in developing their positions and recommendations on energy issues.

Types of Hydrocarbons

Fossil Fuel is a collective term for hydrocarbons in the gaseous, liquid, or solid phase. The global fossil fuel endowment includes the following: coal, crude oil (including condensate), natural gas liquids, and natural gas.

- Coal is the altered remains of prehistoric plants that originally accumulated in swamps and peat bogs. It is organic sedimentary rock that has undergone various degrees of coalification, which determines its current physical properties.

- **Crude Oil** is defined as a mixture of hydrocarbons that exists in a liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface production facilities.
- **Natural Gas Liquids** (NGLs) are those portions of the hydrocarbon resource that exist in gaseous phase when in natural underground reservoir conditions, but are in a liquid phase at surface conditions (that is, standard temperature and pressure conditions: 60°F/15°C and 1 atmosphere).
- **Natural Gas** is a mixture of hydrocarbon compounds existing in the gaseous phase or in solution with oil in natural underground reservoirs at reservoir temperature and pressure conditions and produced as a gas under atmospheric temperature and pressure conditions. Natural gas is principally methane, but may contain heavier hydrocarbons (such as ethane, propane, and butane) and inert compounds.

Hydrocarbon Assessment Terminology

Hydrocarbons In Place

The endowment, or hydrocarbons in place in an accumulation or in all accumulations in the world, is significant because some fraction of the in-place endowment is always the goal for extraction and conversion to resources. In-place estimates have relatively high uncertainty and require assumptions and constraints in the analysis. As an illustration, the following global in-place estimates are based on analyses by Rogner,[1] Schollnberger,[2] and others:

- **Coal:** 14,000 billion short tons (Rogner: grades A-E, several geographical areas not assessed)
- **Oil:** 15,000 billion barrels (Schollnberger: mid-case—included conventional, heavy, very heavy, and NGLs; not including oil shales)
- **Gas:** 50,000 trillion cubic feet (Schollnberger: mid-case—includes conventional, tight gas, and coal-bed methane; not including gas hydrates)

While these volumes can only be estimated within wide ranges, they indicate the fossil hydrocarbon endowment is large compared to past produced volumes and current reserve estimates. However, only a fraction of the total hydrocarbon endowment can ever be technically converted into recoverable resources and producible reserves. While continuing technical advances are likely to increase this fraction as they have in the past, economic, political, and environmental factors will be important in determining the likely size of the recoverable resource base.

Resources and Reserves

Resources and reserves are the strategically important elements of the hydrocarbon endowment remaining to be produced. Figure 2-5 shows various classifications of reserves and resources.

- **Resources** are those quantities of the endowment estimated, as of a given date, to be potentially recoverable from known or undiscovered accumulations. Resources are not considered commercial at the time of estimation.
- **Reserves** are those estimated quantities of the endowment anticipated to be commercially recoverable from known accumulations from a given date forward. Reserves must satisfy four criteria: they must be *discovered, recoverable, commercial,* and *remaining* based on the development technologies currently applied.

Reserves and Total Resource Growth

Growth in estimated reserves or resources occurs in almost all hydrocarbon systems in the world. Many analysts consider it to be the most important source for potential additional reserves in mature petroleum regions such as the United States. Many factors can increase the estimated ultimate recovery from known accumulations, including improved: (1) data as a field matures, (2) recovery techniques, (3) imaging for well placement, and (4) completion efficiency. Additions to reserves from growth are volumetrically significant, as most additions to world reserves in recent years are from growth of reserves in known accumulations rather than new discoveries.

The importance of reserves growth to estimating available future oil is the subject of considerable debate. One challenge stems from the fact that not all countries report reserves in the same way. For example, the percentage and rate of conversion of

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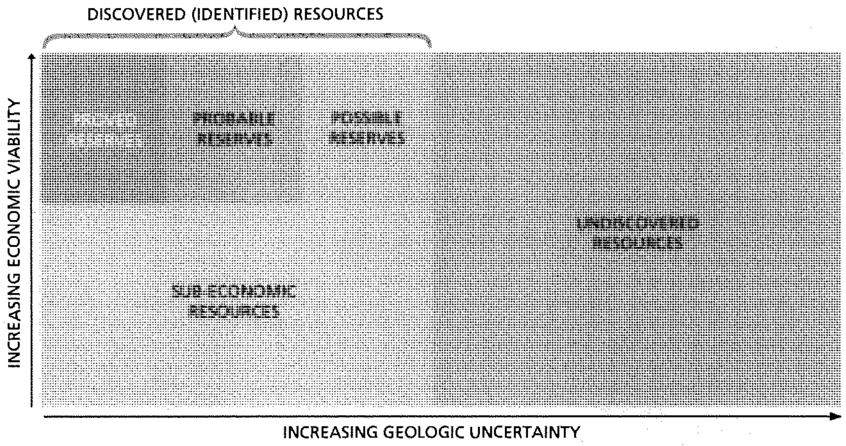
[1] Rogner, H-H., Annual Review – Energy Environment 22:217–62: Institute for Integrated Energy Systems, University of Victoria, 1997.

[2] Schollnberger, W.E., 1998b, Projections of the world's hydrocarbon resources and reserve depletion in the 21st century: Houston Geological Society Bulletin, November, p. 31-37.


DISCOVERED (IDENTIFIED) RESOURCES
INCREASING ECONOMIC VIABILITY
PROVED RESERVES
PROBABLE RESERVES
POSSIBLE RESERVES
UNDISCOVERED RESOURCES
SUB-ECONOMIC RESOURCES
INCREASING GEOLOGIC UNCERTAINTY

Source: McKelvey, V.E., "Mineral Resource Estimates and Public Policy," *American Scientist*, 1972.

FIGURE 2-5. *Example of a McKelvey Diagram, Used to Illustrate the Technical Distinction Between Resources and Reserves*

reserves, and, therefore, the predicted amount of field growth, depends significantly on the reference point. In some cases, the reference point is proved reserves (often referred to as P1). In other cases, the basis is proved plus probable reserves (P1 + P2). The different reference points yield different results for reserves growth.

Oil fields today are also generally smaller and developed more quickly, completely, and with better technology than in the past. This situation raises the possibility that the growth patterns of older fields may no longer be reliable predictors for new development and estimates of future oil.

Undiscovered Resources

Undiscovered resources consist of potential recovery from accumulations that are postulated to exist on the basis of geologic knowledge and theory. There are many aspects of resource endowment that must be present for hydrocarbons to form and be preserved. In a comprehensive resource assessment, each of these aspects is examined and measured, but a great deal about these aspects remain uncertain. Examination of *known accumulations*, together with an analysis of how many have already been discovered in a hydrocarbon province, are used to project numbers and sizes of those which may remain to be discovered. The larger and more obvious potential accumulations are generally drilled first, and usually the largest discoveries are made early in the life of a basin.

Table 2-1 shows the USGS 2000 reserve and resource assessment for conventional oil and gas. Between the reference date of that study (1/1/96) and the end of 2005, approximately 275 billion barrels of conventional oil have been produced. Uncertainty around future additions from growth and undiscovered volumes provides a range of about 2 trillion barrels between low and high estimates.

Conventional and Unconventional Reserves and Resources

Until the 1990s, virtually all estimates of the global oil and gas endowment focused on *conventional* reserves and resources, defined as oils, NGLs, and gas expected to be economically produced using conventional technology and distributed in nature as discrete

	P95	Mean	P5
Oil & Natural Gas Liquids (Billion Barrels)			
Undiscovered and Reserves Growth	776	1,669	2,767
Cumulative and Remaining Reserves		1,676	
	2,452	**3,345**	**4,443**
Natural Gas (Trillion Cubic Feet)			
Undiscovered and Reserves Growth	4,096	8,856	14,770
Cumulative and Remaining Reserves		6,545	
	10,641	**15,401**	**21,315**

Note: P95 refers to a 95 percent probability that the resource size will exceed the estimate, while P5 indicates a 5 percent probability that the resource size exceeds the estimate—thus P95 represents the low end of an assessment and P5 the high end. USGS provides a range of outcomes for reserves growth and undiscovered resources. No range is provided for cumulative production and proved reserves.

Source: United States Geological Survey, 2000.

TABLE 2-1. *Global Resource Estimates for Conventional Oil and Natural Gas*

accumulations. More recent estimates of the endowment include significant additional potential from *unconventional* resources.

In most contemporary definitions, the primary differences between conventional and unconventional petroleum liquids are API gravity and viscosity, i.e., the density of the liquid and how easily it flows. For natural gas, the primary delimiter is the reservoir in which the accumulation is located. Viscosity is the basis of the following definitions:

- **Conventional Oil:** Petroleum found in liquid form (with gravity of greater than 20°API) flowing naturally or capable of being pumped at reservoir conditions without further processing or dilution.
- **Unconventional Oil:** Heavy oil, very heavy oil, oil sands, and tar sands (bitumen) are all currently considered unconventional oil resources. These compounds have a high viscosity, flow very slowly (if at all) and require processing or dilution to be produced through a well bore.
- **Continuous Resources:** The USGS uses the term *continuous resources* to define those resources that may be economically produced but are not found in conventional reservoirs. Continuous accumulations are petroleum accumulations (oil or gas) that have large spatial dimensions and indistinctly defined boundaries, and which exist more or less independently of the water column. Because they may cover hundreds, or even thousands, of square miles, continuous accumulations may occur across a wide range of stratigraphic environments, each of which may have widely varying reservoir properties. Or they may exist in their source rock, never having migrated into a carrier bed or reservoir.

Table 2-2 provides global resource estimates for various types of unconventional oil and gas.

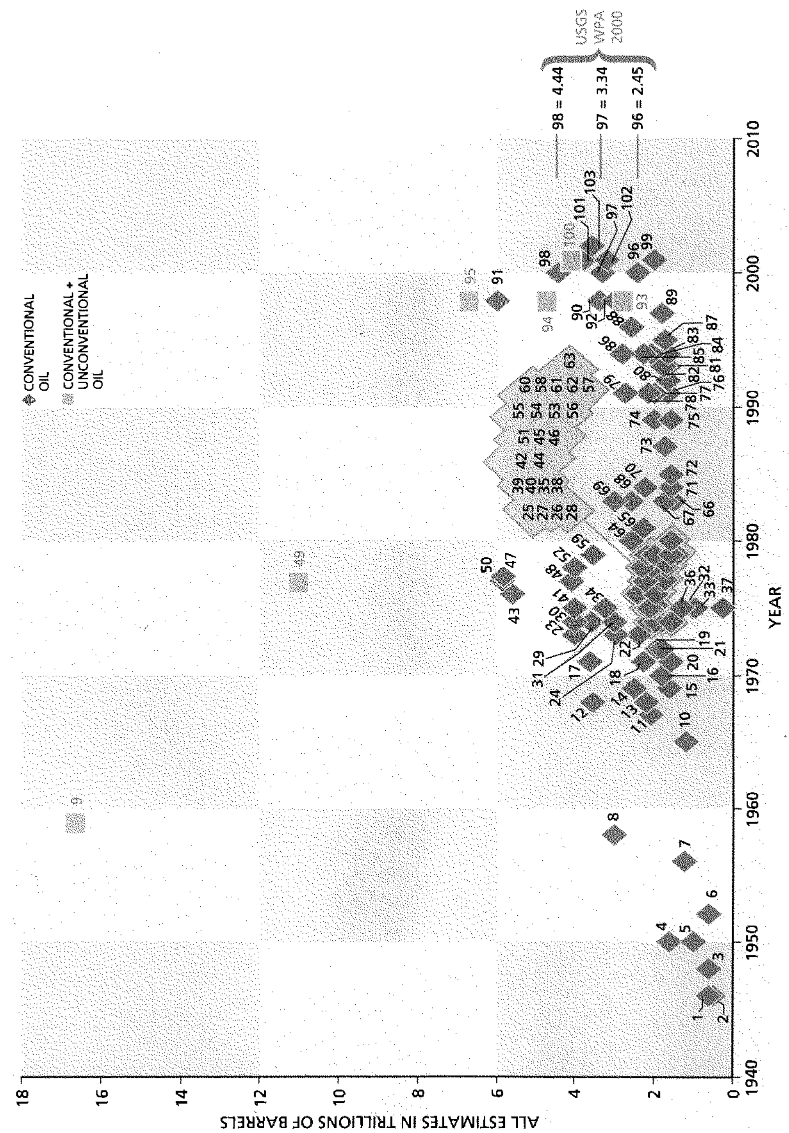
Previous Estimates—Results, Methodology, Differences, and Challenges

Many organizations conduct endowment and resource estimates, for a variety of purposes and with varying methodologies. Figures 2-6 and 2-7 show various global conventional oil and gas endowment estimates plotted against the date of the assessment. Most estimates before 1958 were relatively low, smaller than 2 trillion barrels of oil. Since 1958, both the number and range of estimates have grown.

	Heavy Crude Oil	Tar Sands (Bitumen)	Coalbed Methane	Tight Gas
Oil (Billion Barrels)	761	794		
Natural Gas (Trillion Cubic Feet)			8,225	4,204

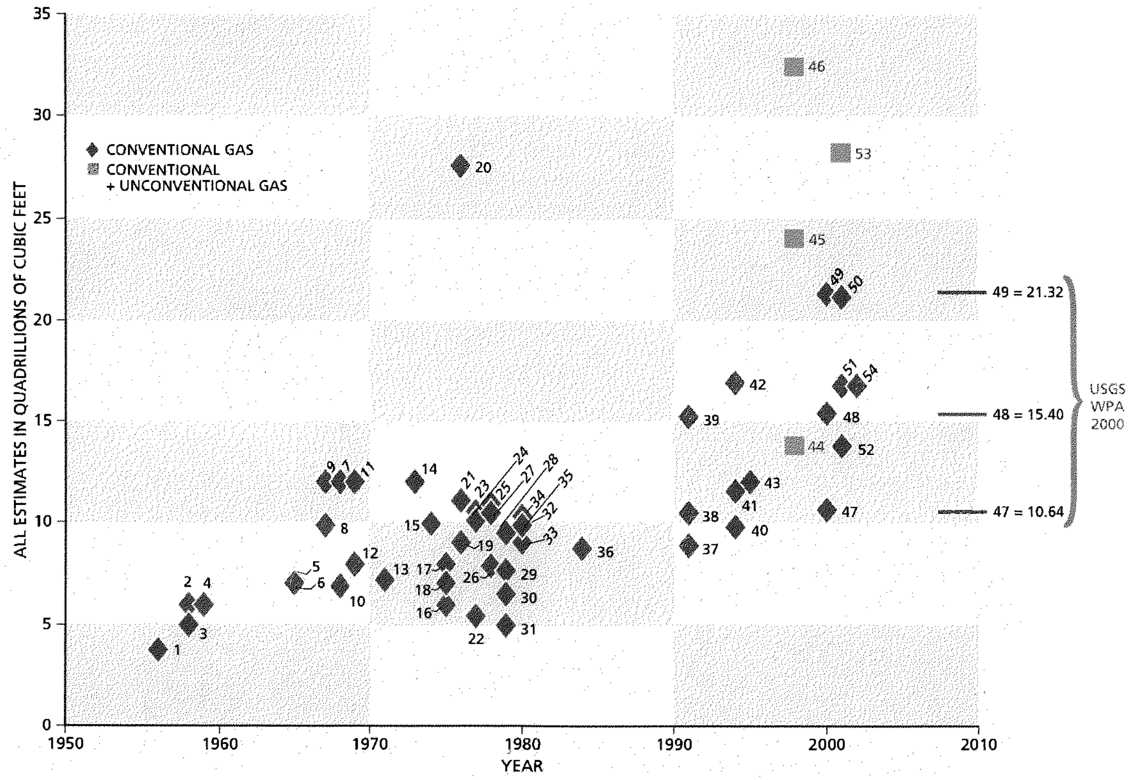
Sources: Oil – BGR (Bundesanstalt für Geowissenschaften und Rohstoffe [Federal Institute for Geosciences and Natural Resources]) *Reserven, Ressourcen und Verfügbarkeit von Energierohstoffen [Availability of Energy Reserves and Resources 1998]*, Germany, 1998. Natural Gas – Rogner, H-H., "World Energy Assessment – Energy and the Challenge of Sustainability," United Nations Development Programme, 2000.

TABLE 2-2. *Global Resource Estimates for Unconventional Oil and Natural Gas*



Source: Ahlbrandt, Thomas S., and Klett, T.R., "Comparison of methods used to estimate conventional undiscovered petroleum resources: World examples," *Natural Resources Research*, 2005.

FIGURE 2-6. World Oil Resource Estimates, 1940 – Present



Source: Ahlbrandt, Thomas S., and Klett, T.R., "Comparison of methods used to estimate conventional undiscovered petroleum resources: World examples," *Natural Resources Research*, 2005.

FIGURE 2-7. *World Natural Gas Resource Estimates, 1950 – Present*

Legend for Figure 2-6

Conventional Oil/Conventional + Unconventional Oil References

1 Duce
2 Pogue
3 Weeks
4 Levorsen (and up)
5 Weeks
6 Pratt
7 Hubbert
8 Weeks
9 Weeks
10 Weeks
11 Ryman
12 Weeks (H)
13 Weeks (L)
14 Hubbert (H)
15 Hubbert (L)
16 Moody
17 Weeks (H)
18 Weeks (L)
19 [illegible]
20 Warman
21 Warman
22 Hubbert
23 Odell
24 Schweinfurth
25 Hubbert (H)
26 Hubbert (L)
27 Kirkby, Adams (H)
28 Kirkby, Adams (L)
29 Parent, Linden
30 Parent, Linden (H)
31 Parent, Linden (L)
32 MacKay, North (H)
33 MacKay, North (L)
34 Moody, Esser (H)
35 Moody, Esser
36 Moody, Esser (L)
37 Moody, Geiger
38 Moody, Geiger
39 Moody, Geiger
40 National Academy of Science
41 Odell and Rosing
42 Barthel, BGR
43 Grossling (H)
44 Grossling (L)
45 Folinsbee
46 Klemme
47 Seidl, IIASA (H)
48 Seidl, IIASA (L)
49 Styrikovich
50 Styrikovich
51 World Energy Conference
52 IFP (4 estimates >4 TBO)
53 Klemme
54 Moody
55 Nehring (H)
56 Nehring (L)
57 Halbouty
58 Halbouty
59 Halbouty
60 Meyerhoff
61 Nehring (H)
62 Nehring (L)
63 De Bruyne
64 World Energy Conference
65 Halbouty
66 Masters
67 Masters
68 Masters
69 Odell and Rosing
70 Masters (H)
71 Masters (L)
72 Martin
73 Masters
74 Bookout
75 Campbell
76 Campbell
77 Masters
78 Masters
79 Masters
80 Campbell
81 Campbell
82 Laherrere
83 Campbell
84 Masters
85 Masters
86 Masters
87 Campbell
88 MacKenzie
89 Campbell
90 BP
91 Odell (H)
92 Odell (L)
93 Schollnberger
94 Schollnberger
95 Schollnberger
96 USGS
97 USGS
98 USGS
99 Deffeyes
100 SHELL
101 SHELL (H)
102 SHELL (L)
103 Edwards

Legend for Figure 2-7

Conventional Gas/Conventional + Unconventional Gas References

1 MacKinney
2 Weeks (H)
3 Weeks (L)
4 Weeks
5 MacKinney
6 Weeks
7 Ryman
8 SHELL
9 MacKinney
10 Weeks
11 Hubbert (H)
12 Hubbert (L)
13 Weeks
14 Hubbert
15 Parent, Linden (and up)
16 Adams and Kirkby (H)
17 Moody, Geiger
18 National Academy of Science
19 Barthel, BGR (and up)
20 Grossling (H)
21 Grossling (L)
22 International Gas Union
23 Parent, Linden (H) (and up)
24 Parent, Linden (L)
25 Desprairies (H)
26 Desprairies (L)
27 McCormick, AGA
28 Bois
29 Meyerhoff
30 Nehring (H)
31 Nehring (L)
32 Parent, Linden (H) (and up)
33 Parent, Linden (L)
34 Schubert
35 World Energy Conference
36 Masters
37 Masters
38 Masters
39 Masters
40 Masters
41 Masters
42 Masters
43 Rice
44 Schollnberger
45 Schollnberger
46 Schollnberger
47 USGS
48 USGS
49 USGS
50 CEDIGAZ (H)
51 CEDIGAZ (L)
52 SHELL
53 SHELL
54 PGB

Resource estimates as seen in Figures 2-6 and 2-7 are snapshots in time. They represent only what has been assessed: particular parts of the world (basins, plays, regions, or countries); specific commodities (oil, natural gas, conventional, unconventional); and data available at the time. Assessing additional types of resources or additional parts of the world can greatly change the estimates. Resource estimates are one basis of forecasting. Other important factors and risks can also significantly shape forecasted production profiles over time.

Finally, comprehensive assessments built from global, detailed geological studies are very limited. While the USGS survey of resources in 2000 is the most comprehensive U.S. agency assessment and the basis of many forecasts, the strategic importance of endowment and resource estimates emphasize the ongoing need for comprehensive, up-to-date data. For a detailed discussion of the hydrocarbon resource endowment, see the Endowment Topic Paper on the CD included with the report.

Primary Energy Mix

Energy forecasts generally show that fossil fuels will dominate the total energy mix, although their share may decline from today's 85 percent to slightly more than 75 percent in 2030. In several forecasts, gas and coal are expected to increase their share. Oil's share of the total primary energy mix is generally forecast to decrease, even as absolute oil volumes grow, principally for transportation use. While renewable energy, gas-to-liquids, coal-to-liquids, and coal-to-gas grow rapidly from a low base, they remain a smaller share of the energy mix in 2030. In any case, the enormous scale of global energy means that a prospective 10 percent decline in fossil fuel share will require a major reallocation of investment, infrastructure, and technical effort.

Historical Energy Consumption

Figure 2-8 shows that global primary energy consumption has grown just over 2 percent per year since 1980. U.S. primary energy consumption has grown just over 1 percent per year since 1980, as shown in Figure 2-9. Most demand forecasts include historical energy mix and consumption patterns as inputs to their projections.

Projected Energy Consumption

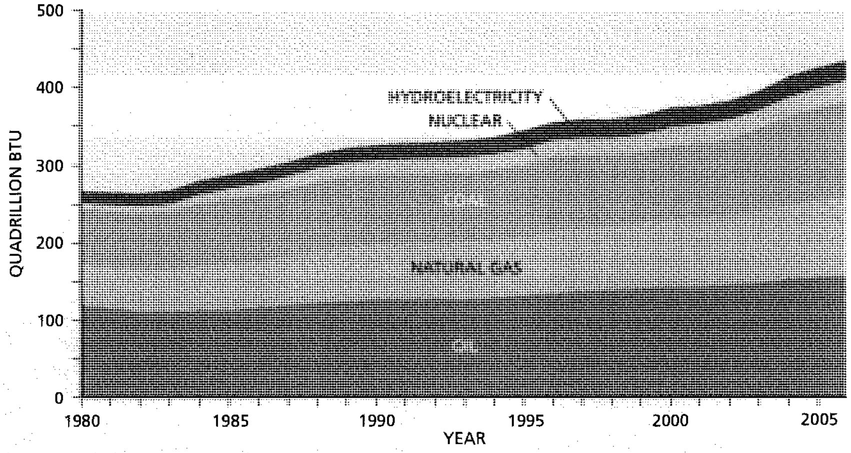
Energy forecasts are typically based on macro-economic inputs and historical factors that drive global energy consumption. Reference Cases generally use business-as-usual assumptions that do not consider (1) potential global supply disruptions resulting from geopolitical events, (2) technology breakthroughs that could substantially enhance supply or reduce demand, and (3) significant shifts in energy policies. In addition, most outlooks make separate forecasts for various scenarios that would materially change outcomes, such as carbon constraints or significant price changes. The Energy Demand chapter of this report provides an extensive discussion of demand outlooks that supplements the summary in this section.

Fossil fuels are projected to dominate the total global energy mix, contributing approximately 75 percent of global energy supplies in 2030 compared with some 85 percent today (Figure 2-10). Most business-as-usual outlooks show that total energy demand in 2030 will be 40 to 70 percent higher than the 2005 level of 425 quadrillion Btu. These forecasts assume the global fossil energy system will provide supply and infrastructure required to meet the increased demand.

Outlooks that assume no further restrictions on carbon dioxide emissions generally do not include significant carbon capture and sequestration (CCS). These forecasts show a significant increase in global carbon dioxide emissions by 2030. In the case of carbon-constrained energy use, projected reduction in carbon dioxide emissions is achieved through reduced energy consumption, fuel switching, and carbon capture and sequestration.

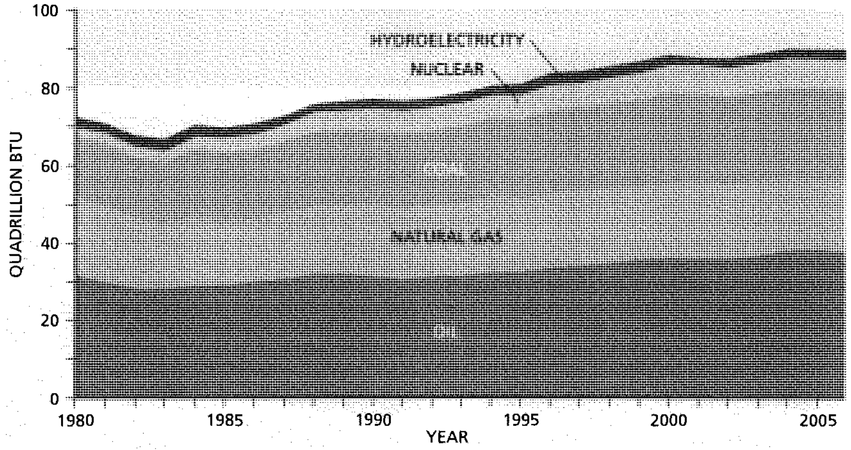
Gas and coal are generally expected to increase their share of the total primary energy mix, while the oil share continues to decrease even as oil volumes in most cases continue to grow. Figure 2-11 projects four EIA and IEA cases for global energy consumption to 2030. Crude oil continues its trend towards becoming primarily a source of transportation fuels. Renewable energy, as well as gas-to-liquids, coal-to-liquids, and coal-to-gas grow rapidly from a low base, but their shares of the total mix remain relatively small.

Carbon constraints without nuclear energy and CCS increase the demand for natural gas. However, in some carbon-constrained cases, nuclear power increases substantially as a share of total energy, although it remains flat in reference forecasts. The biomass share of total energy expands dramatically in several constrained cases, with the biggest impacts occurring after 2030.



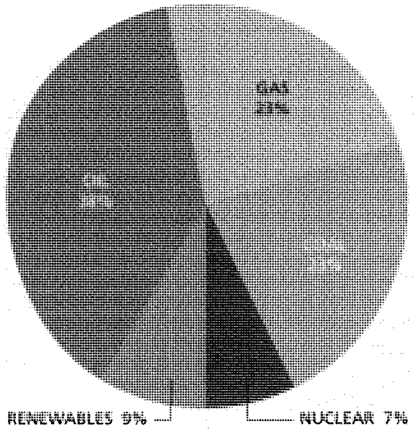
Source: *BP Statistical Review of World Energy 2007.*

FIGURE 2-8. *Global Primary Energy Consumption, 1980-2006*



Source: *BP Statistical Review of World Energy 2007.*

FIGURE 2-9. *U.S. Primary Energy Consumption, 1980-2006*



Source: International Energy Agency, *World Energy Outlook 2006.*

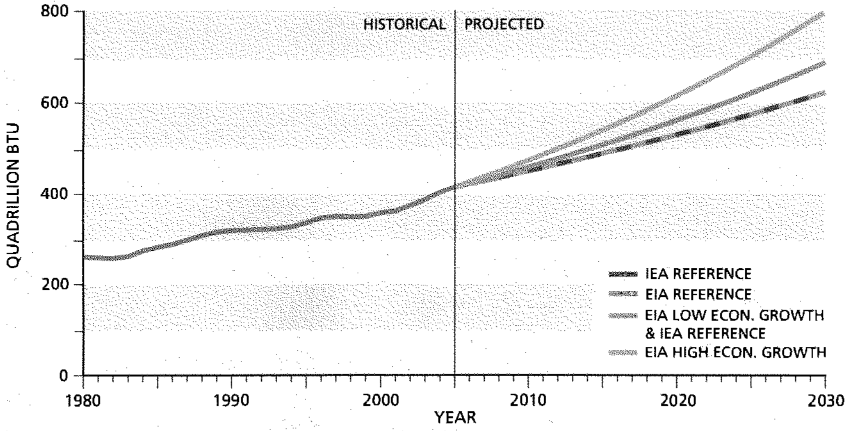
FIGURE 2-10. *Global Energy Consumption Shares in 2005*

Oil and Natural Gas Supply

Oil

Total energy supply forecasts are wide-ranging, based largely on variations in oil demand outlooks and differing views on the deliverability of oil. Some views of future oil production consider lower limits on the available recoverable oil resource while others extrapolate historical successes in expanding the recoverable resource base. Current endowment and resource assessments for both oil and gas indicate large in-place volumes and development potential. The gas resource base is more than adequate to meet the increased gas production typically anticipated by energy outlooks over the study period. However, this will require replacing 50 percent of existing gas reserves by 2030.

There is more uncertainty about the capacity of the oil resource base to sustain growing production rates. The uncertainty is based on (1) the rate and timing at which significant quantities of unconventional oil enter the supply mix, and (2) the ability of the oil industry to overcome growing supply-development risks.



Sources: International Energy Agency (IEA) *World Energy Outlook 2006;* and Energy Information Administration (EIA) *International Energy Outlook 2006.*

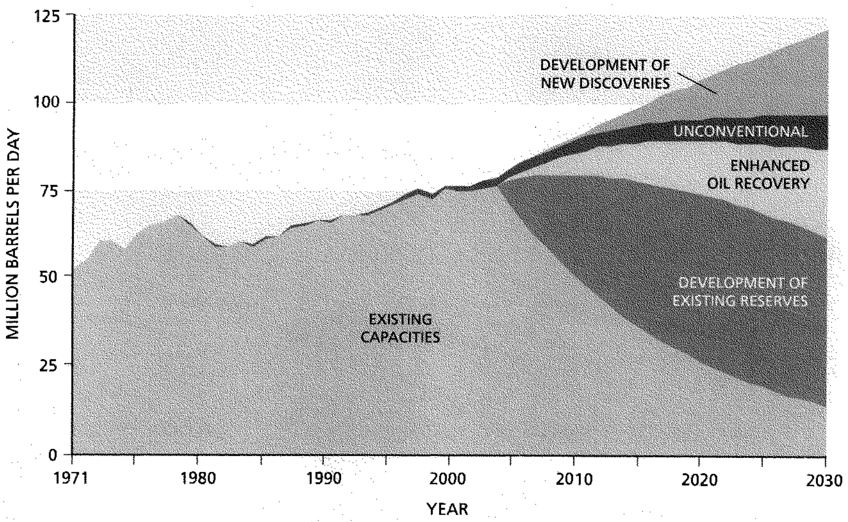
FIGURE 2-11. *Projected Global Energy Consumption*

The finite nature of the oil endowment and the prospect that production will reach a peak and eventually decline contribute to the debate about oil supply. The timing of the decline is subject to interpretation because:

- The underlying decline rate in currently producing fields is not universally well-reported. Many observers think that 80 percent of existing oil production will need to be replaced by 2030—in addition to the volumes required to meet growing demand. Figure 2-12 is an illustrative example showing various components of total liquids supply as depicted in the IEA World Energy Outlook 2004. Resource components such as existing production capacity, booked reserves, enhanced oil recovery, etc., contribute to virtually all projections of liquids supply, although the combination and timing of components may differ.
- Opinions differ about the world's estimated ultimately recoverable oil resource and whether fields can continue to increase production if more than half of today's estimated ultimately recoverable resources (URR) has already been produced.
- The increased cost of producing oil (both conventional and unconventional including alternative liquids) raises concerns about the timing and scale of major energy development.
- Timing of development for alternative liquid supplies at scale is uncertain.

Supply outlooks reflect uncertainty about oil supplies, at least partly based on recent difficulties in increasing production. Forecast global liquids production in 2030 ranges from less than 80 million to 120 million barrels per day, compared with current daily production of approximately 84 million barrels.

Conventional oil is forecast to contribute the largest share of global liquid supply, principally through increased production in Saudi Arabia, Russia, Venezuela, Iran, and Iraq. Unconventional oil such as Canadian and Venezuelan heavy oil and U.S. oil shale is also



Source: IEA, *World Energy Outlook 2004.*

FIGURE 2-12. *Illustrative Total Liquids Supply*

likely to play a growing role in liquids supply. However, most forecasts project that unconventional oil, together with coal-to-liquids (CTL) and gas-to-liquids (GTL), is unlikely to exceed 10 million barrels per day globally by 2030.

Natural Gas

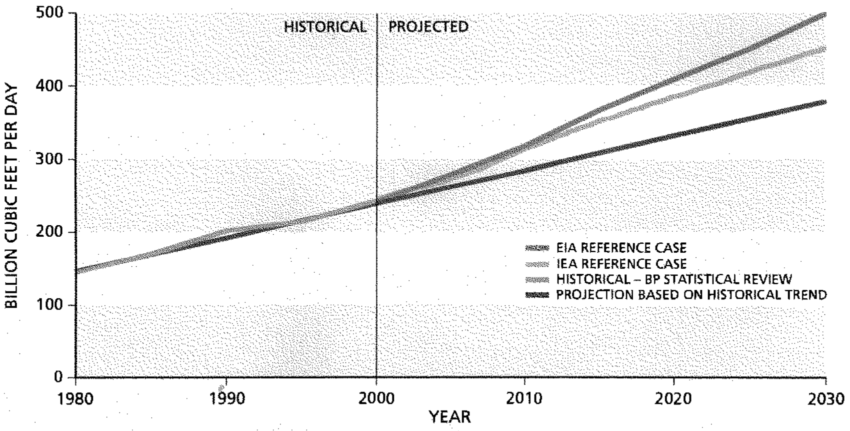
Most outlooks project that natural gas production to 2030 will grow faster than it has historically, ranging from 400 billion to 500 billion cubic feet per day. The EIA high-production cases, for example, are at the upper end of the range, with a projected doubling of production from today's 250+ billion cubic feet per day. Figure 2-13 shows the EIA and IEA projections for natural gas production.

While there is some concern about the gas resource base relative to projected demand growth, most outlooks consider it more than adequate to meet demand. However, nearly two-thirds of natural gas resources are concentrated in four countries, Russia, Qatar, Iran, and Saudi Arabia, which are projected to show the biggest growth in production. Since these countries are relatively distant from likely consuming regions, global gas supply chains will be needed to connect producers and markets—similar to the trading system that has been developed over decades for oil. In North America, major new additions to gas resources are possible, given expansion of unconventional U.S. gas production and development of infrastructure to transport Arctic gas. Generally, production growth in resource-owning countries, creation of a global gas supply chain, and very large infrastructure investments are all elements of risk in matching projected gas supply to demand.

Coal

The global coal endowment is considerably larger than either the oil or gas endowment, with only a small portion of the resource base having been produced to date. The United States, Russia, China, India, and Australia hold over three quarters of the world's proved coal reserves. As other fossil fuels become relatively more costly or difficult to secure, these large resource owners may increase domestic coal production and use. However, the same constraints that apply to other resources may also apply to coal development globally and in the United States:

- Environmental constraints including carbon management, water use, land use, and waste disposal.



Sources: Energy Information Administration (EIA), *International Energy Outlook 2006;* International Energy Agency (IEA), *World Energy Outlook 2006;* and *BP Statistical Review of World Energy 2006.*

FIGURE 2-13. *Projected Global Natural Gas Production*

- Limits on transport and delivery infrastructure development within local markets.

These environmental and infrastructure limitations are potentially more severe for coal than for other conventional fossil fuels.

Business-as-usual energy outlooks, without significant environmental constraints, generally show a 50 to 60 percent increase in global coal production between 2005 and 2030. Most coal production growth will occur in rapidly expanding Asian economies, with China and India accounting for nearly 80 percent of the annual increment. Figure 2-14 shows projected growth in coal production in business-as-usual cases without carbon constraints.

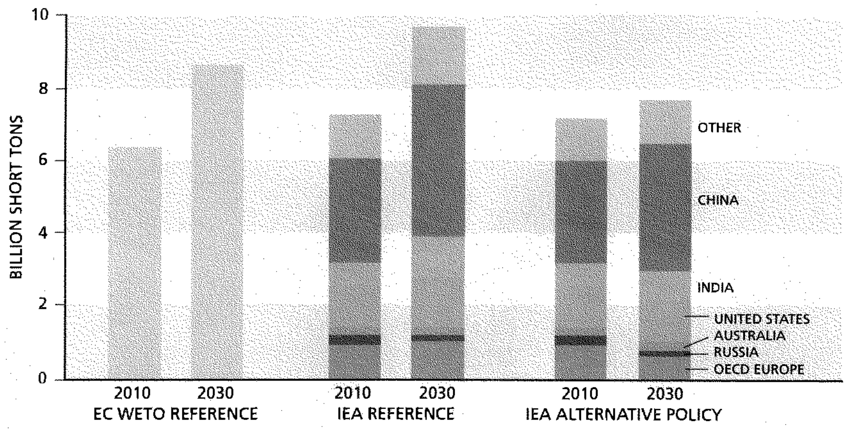
In alternative policy/carbon constrained cases that do not consider carbon CCS, coal production is generally flat-to-declining from today's levels, as energy demand is met by fuels with a lower carbon impact. Where CCS is considered, the balance between growth in natural gas demand, biomass energy sources, and coal provides for growth in coal production and use.

Most technology development for new uses of coal, such as coal-to-liquids and CCS, addresses the technical, environmental, and economic barriers to increasing coal use. The delivery infrastructure needed for expanding coal use appears to receive less attention.

Biomass

Biomass refers to wood, cultivated crops, or natural vegetation that potentially can be converted to energy. As with coal, biomass is an abundant, indigenous resource for the United States and some other major centers of energy demand. Accordingly, biomass could be seen as an important option to reduce risks related to supply security. First-generation biomass conversion to fuels has been based on crops such as sugarcane, corn, and soybeans, which are also food sources, giving rise to concerns about crop competition among food, animal feed, and fuel use. Second-generation conversion technologies such as cellulosic ethanol seek to address these concerns by using plant waste as a feedstock. See the Biomass section later in this chapter for a discussion of potential sources of biomass energy.

Numerous studies have assessed the potential of agriculture to produce both energy and food for the



Sources: European Commission, *World Energy Technology Outlook 2050* (EC WETO), 2006; and International Energy Agency (IEA), *World Energy Outlook 2006*.

FIGURE 2-14. *Projected Growth in Global Coal Production without Carbon Constraints, 2010 to 2030*

world. While conclusions vary, most estimate that 250 to 500 exajoules (approximately 238 to 476 quadrillion Btu) of biomass energy could be produced while still feeding a growing global population. These estimates represent a potentially substantial contribution to a 2030 global energy demand projected at about 740 exajoules, or 702 quadrillion Btu, in the EIA *International Energy Outlook 2007* (IEO 2007) Reference Case. Meeting both food and large-scale fuel demand would require successfully developing and deploying second-generation crop production and conversion technology. Most business-as-usual forecasts (EIA, IEA, European Commission, and aggregated proprietary outlooks) suggest that biomass will meet 5 to 10 percent of total energy demand in 2030, comprising less than 5 million barrels per day of total global liquids production. Other forecasts that are not business as usual show substantially higher biofuels production.

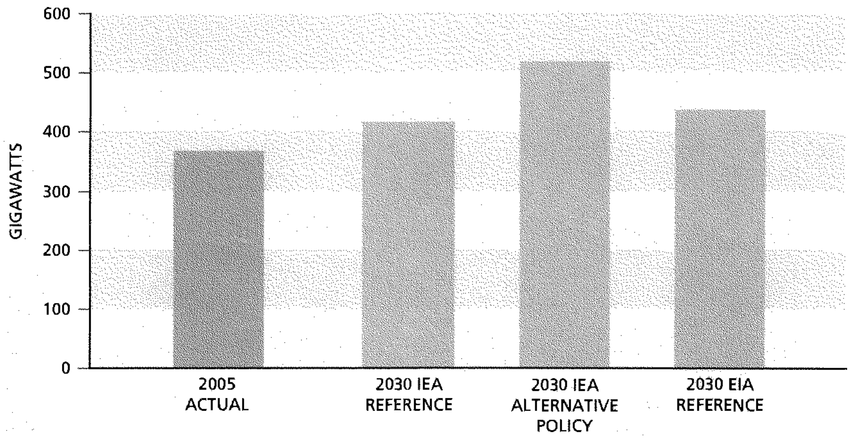
As with any large-scale energy source, technical, logistical, and market requirements will need to be met for biofuels to achieve their potential. Milestones along this development path will include: investments in rail, waterway, and pipeline transportation; scale-up of ethanol distribution; and technology deployment for cellulosic ethanol conversion. The time frames required in many cases to move technology from concept to full-scale application may make such sources available only later in the outlook period. For a detailed discussion of biomass, see the Biomass Topic Paper on the CD included with the report.

Nuclear

Nuclear power faces unique controversy based on concerns about safety, security, and management of the nuclear fuel and waste cycle. In addition, the capital intensity of nuclear generation increases the risk profile for investors. Accordingly, nuclear power's current 5 to 6 percent of the total energy mix is not projected to increase over the study timeframe, unless nuclear generation is promoted for policy objectives such as limiting carbon dioxide emissions or enhancing energy security. Figure 2-15 shows projected global growth in the installed nuclear power base.

Non-Bio Renewables

Hydroelectric generation has historically been the dominant non-bio source of renewable energy, providing vast amounts of electricity at very low marginal



Sources: Energy Information Administration (EIA), *International Energy Outlook 2006;* and International Energy Agency (IEA), *World Energy Outlook 2006.*

FIGURE 2-15. *Projected Global Installed Nuclear Power Base*

cost of production. Most hydroelectric resources have been tapped in industrialized nations, while there may be limited additional opportunities in industrializing and economically developing nations. Wind and solar energy, which have shown significant growth in recent decades, are forecasted to grow several times faster than overall energy demand, starting at their current base of less than 2 percent of global energy supply. Geothermal presents more limited opportunities for new supplies and is not expected to outpace global energy supply growth.

Non-bio alternative and renewable energy sources require unique technologies that tap natural energy flows in different ways. Collectively, however, they have several common characteristics, in addition to mainly producing power rather than fuels: (1) high initial capital costs of construction or fabrication and installation; (2) low operating costs and minimal fuel or feedstock expenses; and (3) possible economies of scale that have not been fully developed. Some of these technologies require energy storage solutions to offset highly variable power production rates. As costs have risen for developing and converting fossil resources to power and fuel, non-fossil options have become more economically competitive and attractive for their potential renewable and environmental benefits. However, large-scale development of these energy options raises concerns about their potential ecological impacts.

Most forecasts of future energy supplies suggest that the total contribution from new renewable and alternative energy sources will remain small for the next two decades since they start from a relatively small base. Although the potential contribution of solar and wind power, waves, tides, and geothermal energy is vast, the economic cost of harnessing most of these sources at scale has been high, relative to other sources such as fossil fuels, hydro, and nuclear. However, the cost differential continues to decline. As with any energy source, resolution of ecological, technical, and commercial issues will favor some technologies rather than others.

Energy Conversion and Delivery Infrastructure

Finding and developing resources are two steps in the energy supply chain. Converting the resources to usable products and delivering them to consumers are equally essential steps that rely heavily on conversion, storage, and transportation infrastructure. However, the total requirements for new infrastructure to 2030 are difficult to assess with any certainty, since energy outlooks generally do not directly account for infrastructure development.

Energy outlooks typically assume supply infrastructure for any energy source will be built if it is economically viable, without regard to potential constraints on financing, permitting, and building. In addition to these potential constraints, the United States faces the issue of maintaining its refining and manufacturing capability, a contentious problem familiar in other industrial sectors. New energy sources will add their own infrastructure demands. Finally, much of the projected increase in global oil and gas trade is likely to move through narrow sea lanes, raising a security challenge for this part of the transportation system. Taken together, infrastructure issues add additional, often unrecognized, risks to prospective energy supply.

ANALYSIS OF ENERGY OUTLOOKS

Oil and Other Liquids

Key Observations—Oil and Other Liquids

- *While crude oil will remain a primary energy source throughout the study time frame and beyond, the capacity of the production and delivery system to increase supply is subject to multiple, increasing risks.*
- *The global in-place oil endowment is very large, but the recoverable resource and the rate at which it can be produced are subject to considerable uncertainty. Forecasted oil production rates vary widely: some rely heavily on OPEC to meet rising demand; others on contributions from unconventional oil and alternative liquids; a third set of forecasts project a production plateau or peak.*
- *As production from existing oil fields declines, future oil supply is likely to rely increasingly on:*
  - *Growth from existing accumulations through use of new technology, better knowledge of reservoir characteristics, or enhanced oil recovery*
  - *Production of unconventional resources such as oil sands or oil shale*
  - *Exploration discoveries, many from new frontiers such as the Arctic and ultra-deepwater*
  - *Conventional oil from hydrocarbon provinces where access is currently restricted.*

Alternative liquids such as biofuels, gas-to-liquids, and coal-to-liquids will also contribute materially to fuel supply.

- *U.S. oil production is generally projected to rise modestly, at best, or decline somewhat during the study time frame. With limited growth from conventional oil sources, the ability to meet expected demand growth will rely increasingly on heavier and unconventional domestic supplies, ultra-deepwater basins, and alternative fuels.*[3]
- *Few projections of domestic supply assume changes in access to U.S. onshore and offshore basins currently under drilling moratoria or subject to significant development restrictions. The time required to explore and develop newly released areas means that production from these areas would appear only later in the study time frame.*
- *Oil production growth after 2015 appears subject to increasing risks as both subsurface and above ground issues become more challenging. The risks include:*
  - *Production declines of many of the world's maturing fields*
  - *Increasingly restricted access to resources*
  - *Unprecedented investment requirements under uncertain fiscal regimes.*

  The risk of not meeting forecasted demand over the study time frame also increases dramatically without sustained technology development and the pursuit of all economically viable fossil and alternative liquid fuel sources.

Crude Oil Endowment

Ancient biomass was converted to oil over millions of years as it was exposed to high temperature and high pressure deep in sedimentary layers. Migration of the oil from source rocks into porous formations at accessible depths in the earth's crust creates the opportunity to locate and produce oil from this endowment.

The global conventional and unconventional oil in place endowment has been variously estimated at 13 trillion to 15 trillion barrels. These barrels represent the estimated total volume of liquid hydrocarbons generated and retained in geologic formations over time. Since oil generates very slowly, the current endowment is relatively fixed and is considered a nonrenewable resource.

Recoverable resources are the portion of the estimated in-place endowment thought to be technically recoverable from their geologic setting. Recoverable resource assessments have generally grown as new technology, or political and economic factors, made more of the in-place endowment recoverable. Based on geological and geophysical data, these assessments require judgments about finding and development costs, extraction efficiencies, oil prices, and other factors. Generally, about one-third of the oil in place is currently assumed to be ultimately recoverable. This assumption yields an estimated 4.5 trillion barrels or more of conventional and unconventional ultimately recoverable oil.

Unconventional Oil Endowment and Resource Development

The global endowment of unconventional oil in place is large, as much as 7 trillion barrels (Figure 2-16). Recovery factors vary widely but are expected to be lower than for conventional oil due to technical challenges and huge capital requirements associated with extraction. Current public and proprietary assessments of URR are similar: 1.5 trillion barrels estimated by Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) and an average 1.7 trillion barrels estimated by IOCs. The estimates are uncertain, but likely to grow as new technologies emerge. Development of heavy oil and oil shale has lagged that of conventional oil because it is more expensive and technically difficult to bring liquids on-line from these sources. Nonetheless, unconventional oil will likely play an increasing role in meeting future energy needs.

Unconventional oil has a much different global distribution than conventional oil. Very heavy oil in Venezuela, oil sands in Canada, and oil shale in the United States account for more than 80 percent of unconventional resources, while conventional oil resources are mainly in the Middle East, West Africa, and Russia. Factors that particularly affect unconventional supplies include technology development, environmental impact, geopolitical climate, capital and operating costs, and material and human resource availability. Uncertainty about each of these factors is a major consideration in projecting future energy supply.

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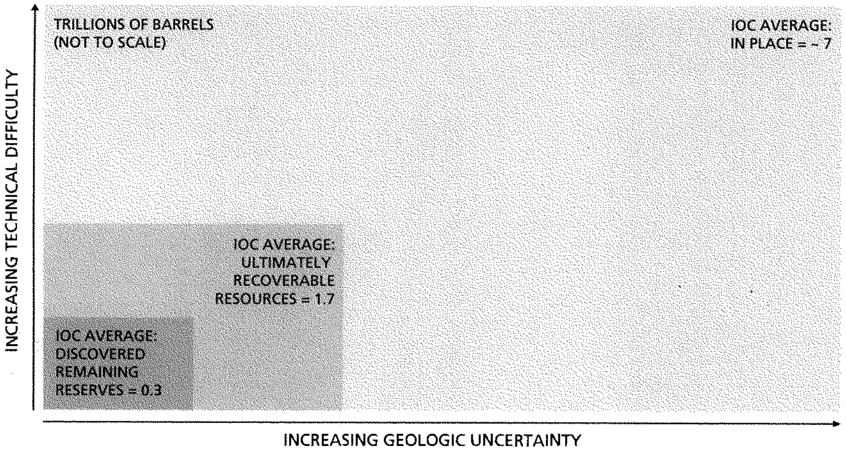
[3] The U.S. Energy Information Administration defines *conventional production* to include crude oil (including lease condensates), natural gas plant liquids, other hydrogen and hydrocarbons for refinery feedstocks, alcohol and other sources, and refinery gains. *Unconventional production* includes liquids produced from energy crops, natural gas, coal, oil sands, and shale.



Source: NPC Survey of Outlooks.

FIGURE 2-16. *Global Unconventional Oil Endowment*

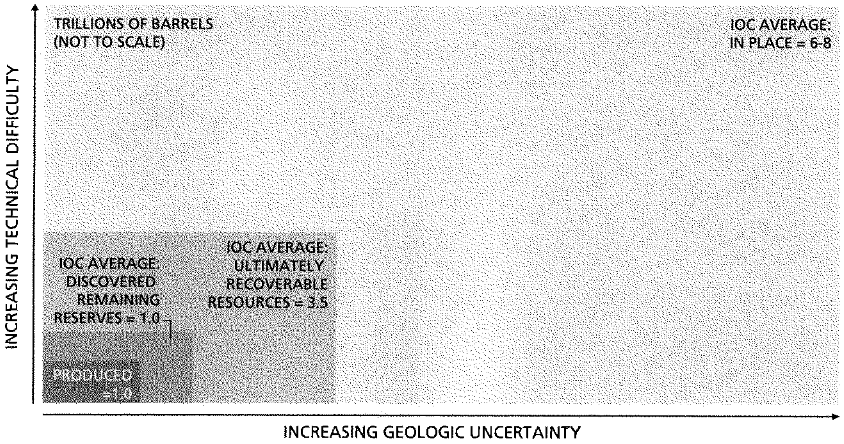
Conventional Oil Endowment and Resource Development

Conventional oil and natural gas liquids have historically received the greatest development attention. The IEA estimates between 6 and 7 trillion barrels of conventional oil and NGL in place, while other estimates are somewhat higher (Figure 2-17). About 1 trillion barrels of the conventional oil endowment have been produced since the late 19th century.

The USGS assessment published in 2000 is one of the few comprehensive, publicly available resource assessments for conventional oil. Many outlooks provided to this study include USGS estimates in their projections after adjusting to reflect newer or proprietary information. For example, EIA will routinely adjust estimated recoverable resources to reflect cumulative production or evolving knowledge that has not been included in USGS assessments.

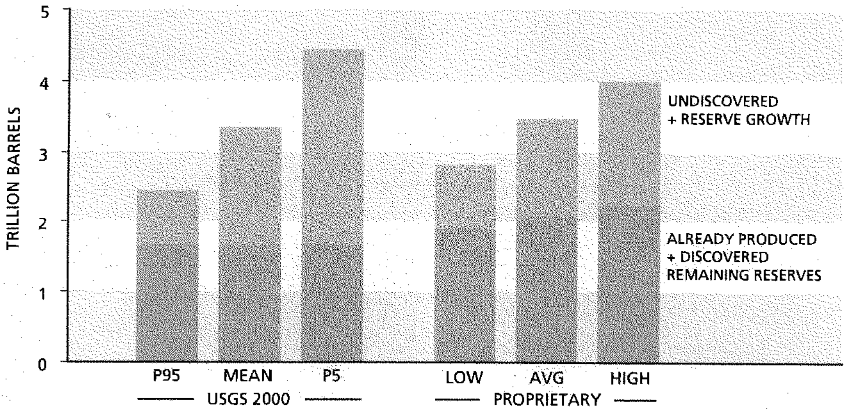
The USGS mean estimate of ultimately recoverable global conventional oil plus NGL is 3.345 trillion barrels at the beginning of 1996. The estimates range from 2.5 to 4.4 trillion barrels, expressed in statistical terms as P95 and P5 estimates, respectively. P95 refers to a 95 percent probability that the resource size will exceed the estimate, P5 indicates a 5 percent probability that the resource size exceeds the estimate. By comparison, IOCs responding to the NPC data survey provided an average projection of 3.5 trillion barrels. The IOC most-likely estimates for ultimately recoverable global conventional oil range from 2.8 to 4.0 trillion barrels. While the USGS and proprietary ranges are statistically different, Figure 2-18 allows approximate comparison.

After taking into account the approximately 1.0 trillion barrels that have been produced to date, the estimated USGS range of remaining, ultimately recoverable global conventional oil and NGL is 1.5 to 3.4 trillion barrels. A higher URR for conventional oil and NGL would sustain oil production growth for a longer time or faster rate, assuming adequate investment and access to the resources. However, the opposite is true if the actual URR is at the lower end of the range. This uncertainty, combined with above-ground risks that could hinder production, fuels the debate about supply outlooks and has a material impact on policy and investment decisions.



Source: NPC Survey of Outlooks.

FIGURE 2-17. *Global Conventional Oil and NGL Endowment*



Note: P95 refers to a 95 percent probability that the resource size will exceed the estimate, while P5 indicates a 5 percent probability that the resource size exceeds the estimate – thus P95 represents the low end of an assessment and P5 the high end.
Source: NPC Survey of Outlooks.

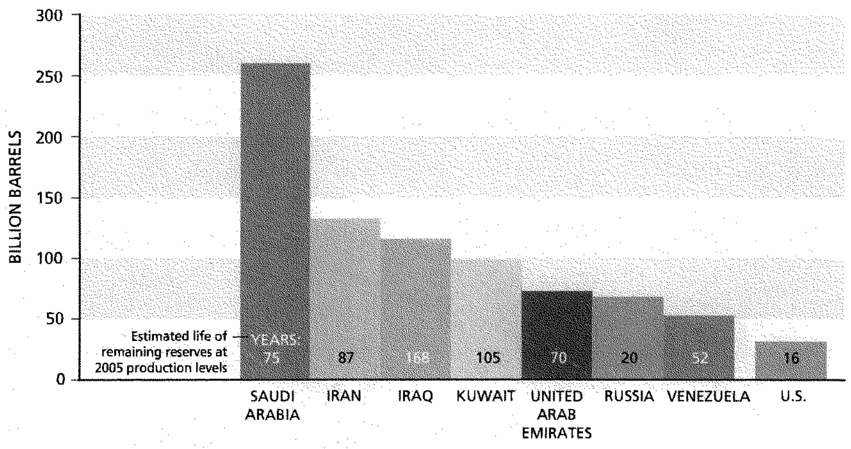
FIGURE 2-18. *Conventional Global Oil and NGL Ultimately Recoverable Resource Estimates*

Reserve Growth and *Undiscovered Resources* are two categories of the USGS 2000 assessment with greatest uncertainty. Reserve Growth refers to the increase in reserves in oilfields. Reserve Growth typically occurs through improved knowledge about the field's productive potential and application of new technology. Reserve Growth accounted for 0.7 trillion barrels of the USGS mean estimated URR at the beginning of 1996. Growth in fields discovered before 1995 added about 65 percent of this volume to proved reserves from 1995 to 2004.[4] Reserve Growth often requires significant additional capital and energy input, especially as recovery factors are increased through enhanced recovery processes.

Undiscovered Resources accounted for an additional 0.9 trillion barrels in the USGS mean case at the beginning of 1996. Only 18 percent of this estimated volume, or about 17 billion barrels per year, has been discovered through exploration in the decade following.[5] Exploration discoveries have shown a declining trend over the past several decades, partly as a result of restricted access to promising hydrocarbon provinces. Significant technology advances, access to unexplored basins, or discovery of very significant fields will be necessary to replace produced resources over the study time frame.

Discovered Remaining Reserves is the portion of URR that is technically and economically producible in the future under current technical and economic conditions. The *BP Statistical Review 2006* estimates that Remaining Reserves grew from 0.9 to 1.2 trillion barrels from 1996-2005, primarily through reserve additions to fields discovered before 1995. The current estimate of reserves is one indicator of how much oil production capacity could be developed in the near to medium term. The quality of reserve additions and undisclosed estimating methods for countries that hold most remaining reserves are significant uncertainties in making supply forecasts.

Globally, conventional oil reserves are concentrated in the Middle East (Figure 2-19). The seven countries with the largest conventional oil reserves account for more than 70 percent of the world total. Saudi Arabia holds approximately 20 percent of conventional reserves, equal to 75 years of production at 2005 rates.



Source: NPC Survey of Outlooks.

FIGURE 2-19. Large Holders of Discovered Remaining Reserves

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[4] K. Chew and P.H. Stark, "Perspectives on Oil Resource Estimates," IHS Energy – 2006.

[5] Ibid.

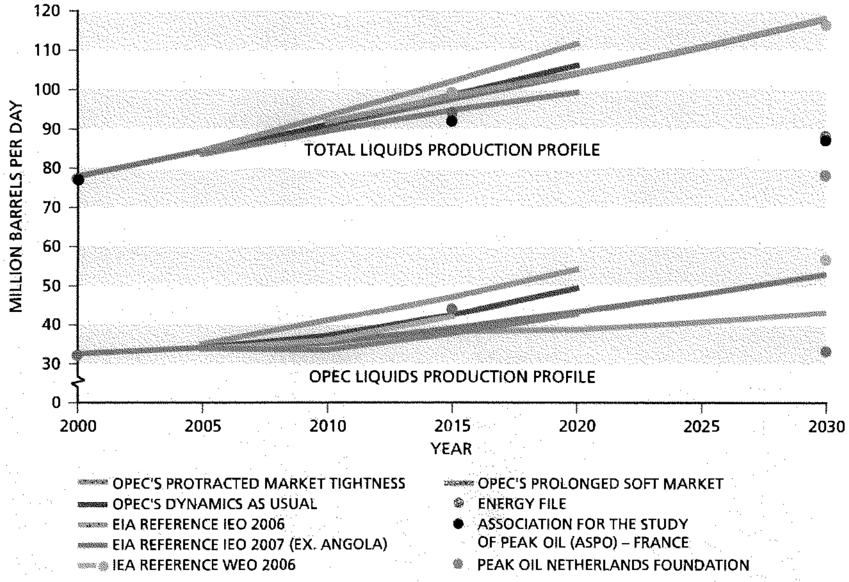
The United States has 31 billion barrels of reserves, 16 years of production at 2005 rates. The estimated life of remaining reserves was calculated by dividing reserves numbers provided to the NPC study by the 2005 production volumes reported in EIA IEO 2007.

The reserves-to-production (R/P) ratio is often used to describe how effectively a country or region has developed oil resources that are currently economically and technically recoverable. High ratios may indicate opportunities for further development and additional rate capacity. Low ratios may indicate that a country has fully developed its available accumulations and production is in decline. Alternately, low R/P ratios may mean that known accumulations have not been fully delineated in order to add them to more certain reserve classifications. The R/P ratio does not by itself indicate remaining production capacity in a field or region. Investment and technology often allow R/P ratios to remain stable over many years even as annual production rates remain unchanged or increase.

Estimates of remaining reserves are not adequate indicators of how much oil remains to be produced under future conditions or potential long-term production capacity. The additional components of URR should be considered for these purposes. Resource size will determine how much oil is likely to be produced in the long term, while the distribution and nature of the oil will determine the likely production rate.

Global Total Liquids Production

Conventional oil will remain the largest source for liquid fuel supply in the near to intermediate term, with forecasts almost unanimously predicting at least modest growth in conventional oil supply for the next 5 to 10 years. However, there are great uncertainties



Source: NPC Survey of Outlooks.

***FIGURE 2-20.** Projected Global and OPEC Total Liquids Production*

about long-term forecasts of oil and total liquid production rates, ranging from business-as-usual cases that show few constraints, to alternative scenarios constrained by the resource base, environmental concerns, or geopolitical issues.

The EIA IEO 2007 Reference Case projects total liquids production of 118 million barrels per day (MB/D) in 2030, with similar estimates in the IEA Reference Case (116 MB/D), the IOC Average (107 MB/D), and Consultant Average (115 MB/D). Higher and lower forecasts include:

- EIA IEO 2007 Low Price: 134 MB/D
- EIA IEO 2007 High Price: 103 MB/D
- Peak Oil Netherlands and Association for the Study of Peak Oil (ASPO) – France: 78-88 MB/D.

The lower production figures in specific cases are driven by carbon constraints, investment constraints, higher oil prices, geological challenges, or other issues. The highest demand projections for 2030 assume favorable development policies in resource-holding countries, technology advances, investment, infrastructure, project completion, and personnel.

Several projections in Figure 2-20 show that total liquids production may not increase after 2015. The lowest total liquids forecasts in 2030 are consistent with a URR at the low end of the USGS range and constraints to developing the conventional oil resource base or alternatives. This set of forecasts projects that liquids production will reach a maximum within the study time frame, although the precise date is uncertain.

Forecasts for declining production are based on various above- and below-ground factors, including: declines in volumes discovered; conventional oil production peaks and subsequent declines in countries such as the United States and the United Kingdom; and anticipated oil production plateaus in countries such as Russia and China. The discussion of peak oil forecasts later in this chapter considers these views more fully.

The production rate for unconventional oil is an additional uncertainty in projected total liquids supply. In the EIA IEO 2007 Reference Case, for example, Canadian oil sands and Venezuelan heavy oils supply 5.2 MB/D in 2030, assuming sustained investment in development. Forecasts that include constraints on development project lower supplies from unconventional sources (Figures 2-21 and 2-22).

Conventional Oil Production

All forecasts project that a few countries, where resources are concentrated, will supply most conventional oil, although specific contributions vary. Geographic concentration generally creates more uncertainty in supply availability or deliverability due to infrastructure, resource, and geopolitical risks; increases the market power of resource holders; and enhances the global role of national oil companies (NOCs).

The EIA and IEA have somewhat different views on the balance of conventional oil supply between OPEC and non-OPEC countries (Figure 2-23). The IEA expects non-OPEC conventional oil production to decline after 2015, with OPEC increasing its share of conventional oil production from 42 percent in 2005 to 52 percent in 2030. The EIA projects that non-OPEC conventional oil production (including Angola) will increase through 2030. In the EIA IEO 2007 Reference Case, OPEC is expected to increase production to meet growing demand, but its share of conventional oil production will only rise to 47 percent.

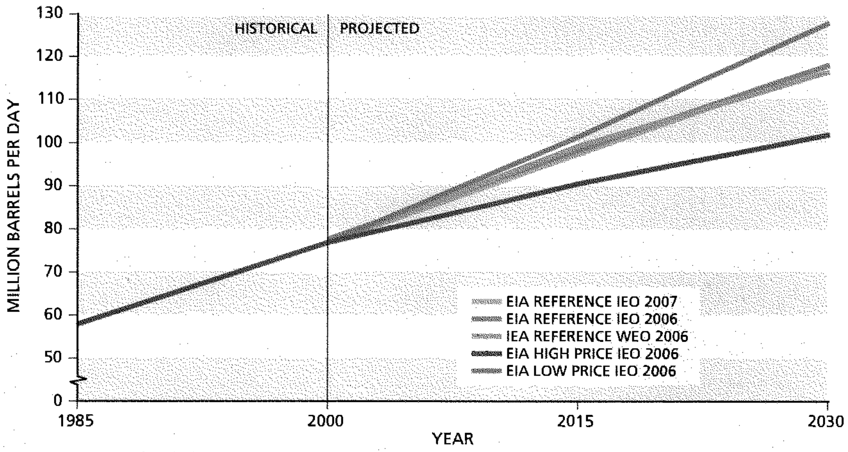
Non-OPEC Production

Estimates for non-OPEC total liquids production vary significantly. Some forecasts indicate that production of non-OPEC conventional oil will decline in the next decade. Other forecasts show production growth through 2030 (Figures 2-24 and 2-25). In the EIA IEO 2007 Reference Case, non-OPEC output rises through 2030. Russia and other Caspian region producers provide about half the increase. Angola is included in non-OPEC production, since most forecasts were completed before it joined OPEC.

By comparison, the IOC Average and all peak oil cases show that non-OPEC production peaks within the outlook period. The IEA WEO 2006 Reference Case shows that non-OPEC production may not grow after 2010 due to high decline rates of currently producing fields and rising costs. The IEA Reference Case also shows that only Russia, Central Asia, and Latin America achieve significant increases in conventional oil production through 2030.

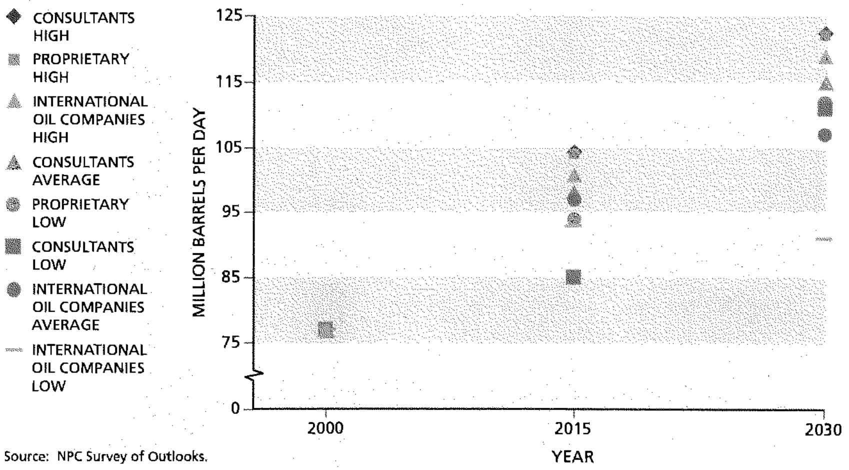
U.S. Production

The United States is the third-largest oil producing country in the world, after Saudi Arabia and Russia. The United States produced 5.2 MB/D of conventional crude oil in 2005, but its production is at best rising



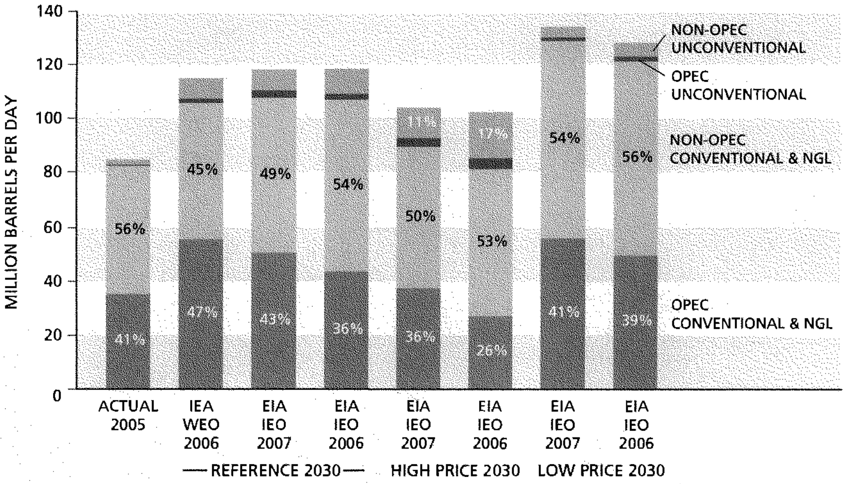
Source: NPC Survey of Outlooks.

FIGURE 2-21. Projected Global Total Liquids Production



Source: NPC Survey of Outlooks.

FIGURE 2-22. Projected Global Total Liquids Production — Proprietary Aggregated Cases



Source: NPC Survey of Outlooks.

FIGURE 2-23. *OPEC and Non-OPEC Total Liquids Production Shares, 2005-2030*

slightly in absolute terms while declining as a share of domestic demand. This production volume is a subset of the conventional production shown in Figure 2-26. Total conventional production is comprised of crude oil, including lease condensates, natural gas plant liquids, other hydrogen and hydrocarbons for refinery feedstocks, alcohol and other sources, and refinery gains.

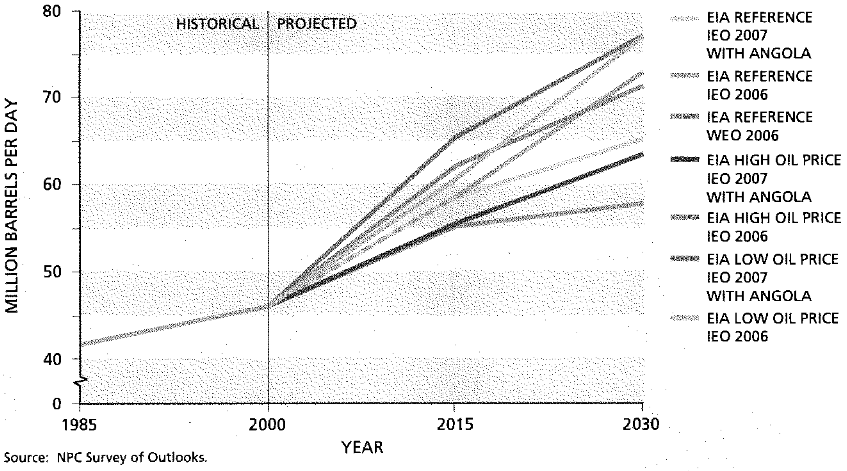
Existing fields, which are maturing onshore and offshore, in Alaska and the lower-48 states, are generally not seen as having the potential to reverse existing declines. The EIA Annual Energy Outlook 2007 (AEO 2007) includes cases showing U.S. conventional crude oil production ranging between 5.25 MB/D and 6.04 MB/D in 2030. An AEO 2007 case that simulated access to the Arctic National Wildlife Refuge (ANWR) sees U.S. crude oil production rising to 6.03 MB/D in 2030, which is about 0.8 MB/D higher than the 2005 rate. By comparison, the IEA Reference Case forecasts U.S. production dropping about 1 MB/D by 2030.

Increasing domestic total liquids production more than marginally would depend on access to basins that have both substantial undeveloped liquid resources and exploration potential and a significant contribution from unconventional oil. Access issues are discussed later in this report. Figure 2-26 shows how substantial production from unconventional sources would affect North American oil imports. Unconventional production is greatest in the EIA High Oil Price case, where imports in all years are below the 2005 level.

Production from Other Large Non-OPEC Countries

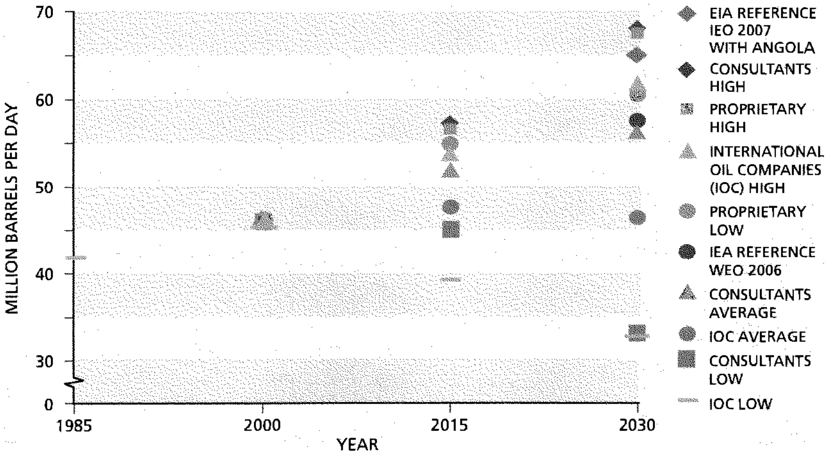
Of the other large non-OPEC producers, Russia will be a critical supply source. All forecasts show Russian production rates increasing from just under 10 MB/D currently to a range of 11 to 13 MB/D by 2030 (Figure 2-27).

Production from two primary sources of U.S. supply, Mexico and Canada, could be headed in opposite directions. Future Mexican production (Figure 2-28) is uncertain. Some forecasts see modest increases, despite recent production declines at a major field. Other forecasts, including the EIA IEO 2007, indicate lower Mexican production in 2015 and 2030 than in 2005. Conventional oil production from Canada is not expected to be material, but expanded development



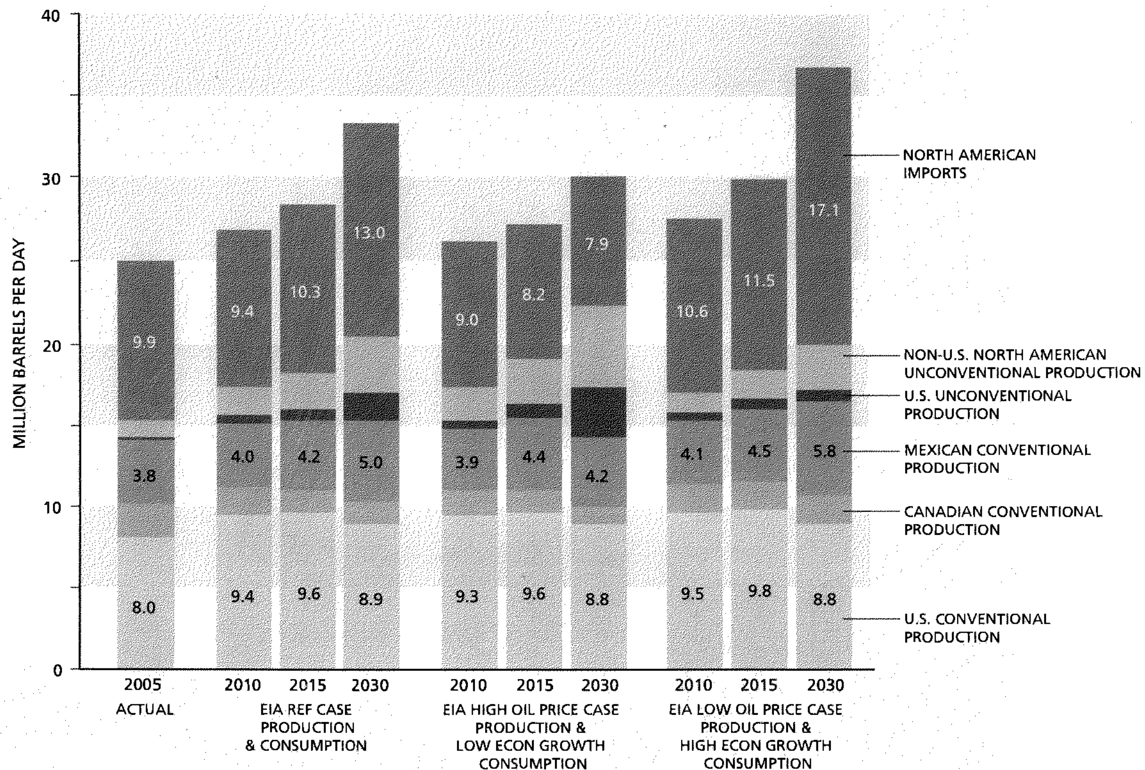
Source: NPC Survey of Outlooks.

FIGURE 2-24. *Projected Non-OPEC Total Liquids Production*



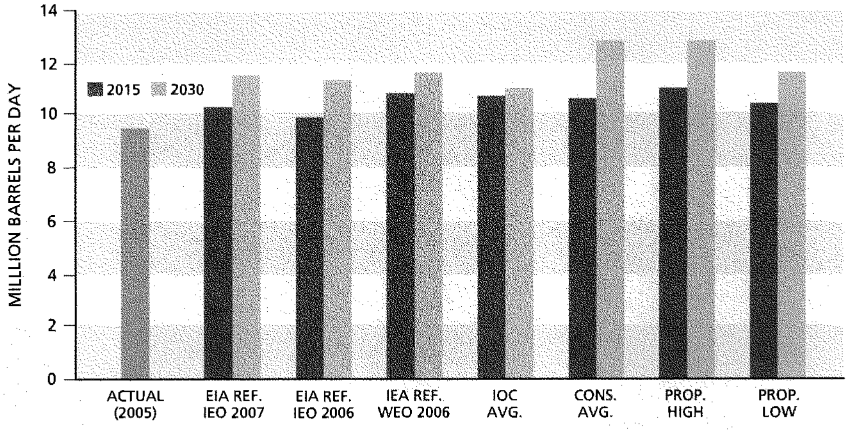
Source: NPC Survey of Outlooks.

FIGURE 2-25. *Non-OPEC Total Liquids Production — Proprietary Aggregated Cases*



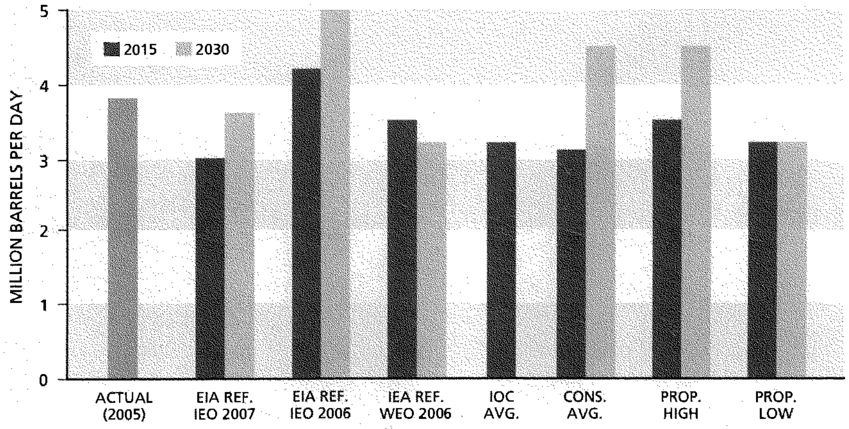
Source: NPC Survey of Outlooks.

FIGURE 2-26. *North American Production and Imports*



Note: IOC = International Oil Companies; CONS. = Consultants; and PROP. = Proprietary.
Source: NPC Survey of Outlooks.

FIGURE 2-27. *Russian Total Liquids Production Outlooks*



Note: IOC = International Oil Companies; CONS. = Consultants; and PROP. = Proprietary.
Source: NPC Survey of Outlooks.

FIGURE 2-28. *Mexican Total Liquids Production Outlooks*

of Canadian oil sands is forecast to bring considerable unconventional production into North American supply (Figure 2-29).

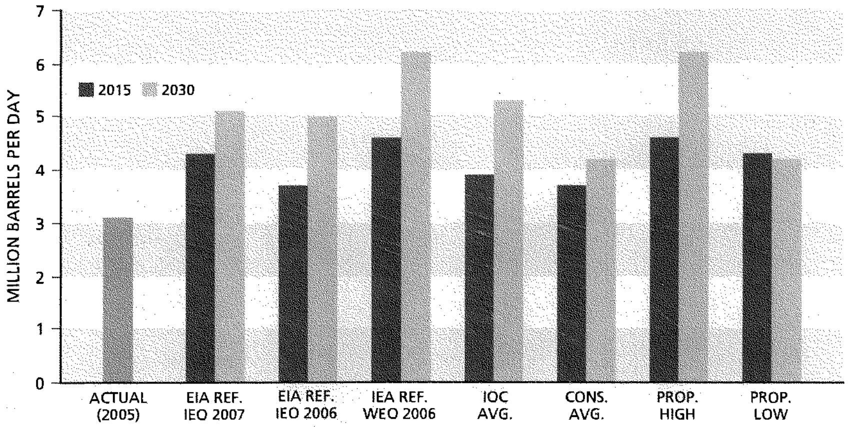
OPEC Oil Production (Excluding Angola)

Almost all long-term forecasts expect production to increase rapidly in OPEC countries. This is especially true of the Middle East, where resources are much larger and production costs generally lower than in other regions. Several forecasts suggest that OPEC is capable of raising total liquids production by 20 MB/D above present levels. The IOC Average case forecasts OPEC production at about 44 MB/D by 2030. The EIA IEO 2007 Reference Case, excluding Angola, projects 53 MB/D. The IEA Reference and Consultant Average cases indicate OPEC production above 50 to 55 MB/D (Figures 2-30 and 2-31). The range of projected OPEC total liquids production, relative to projected global production is shown in Figure 2-32.

Saudi Arabia continues to be the largest OPEC producer in every forecast. The IEA assigns the kingdom a vital role in supplying the global oil market. The IEA WEO 2004 considers timely Saudi Arabian investment in oil-production capacity to be a major determinant of future supply trends. Saudi Arabian production in the IEA case rises from 10.6 MB/D of conventional oil and NGL to 17.3 MB/D by 2030. As Figure 2-33 shows, the IEA has the highest forecast for Saudi Arabia's total liquids production in 2030.

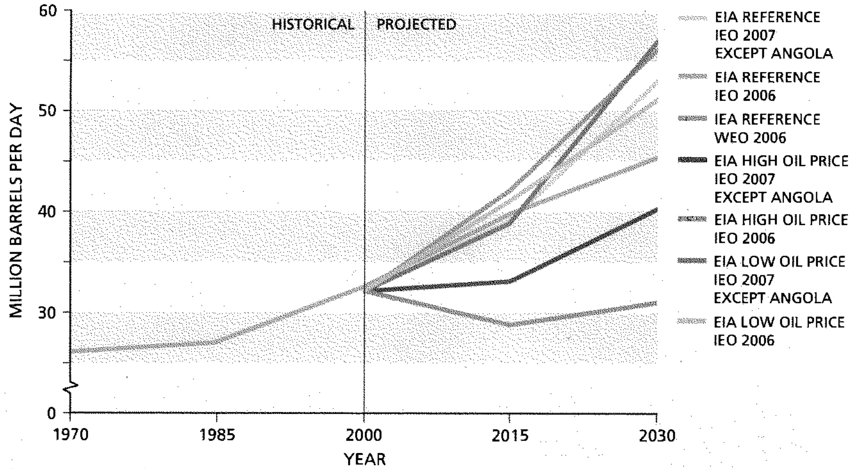
In addition to projected Saudi Arabian production, significant conventional oil production increases from Iraq, Iran, Venezuela, and Nigeria will be needed to meet projected global demand in 2030. Among these producers, the near-term prospects for oil production in Iraq remain very uncertain. Nonetheless, the projected production increases for 2015 differ by a relatively small 0.5 MB/D, from 0.9 to 1.4 MB/D more than in 2005. By 2030, the difference between forecasts expands to 2.3 MB/D. IEA projects Iraqi production as growing to 6 MB/D in 2030, double its current share of OPEC conventional oil production. (Figure 2-34)

Forecasts show a wide range for total Iranian liquids production. The difference between production forecasts for 2015 is 1.5 MB/D, with some showing a drop in production and others showing flat production, or growth of almost 1 MB/D. By 2030, the differences broaden to 1.6 MB/D, with the highest production forecast at more than 6 MB/D. (Figure 2-35)



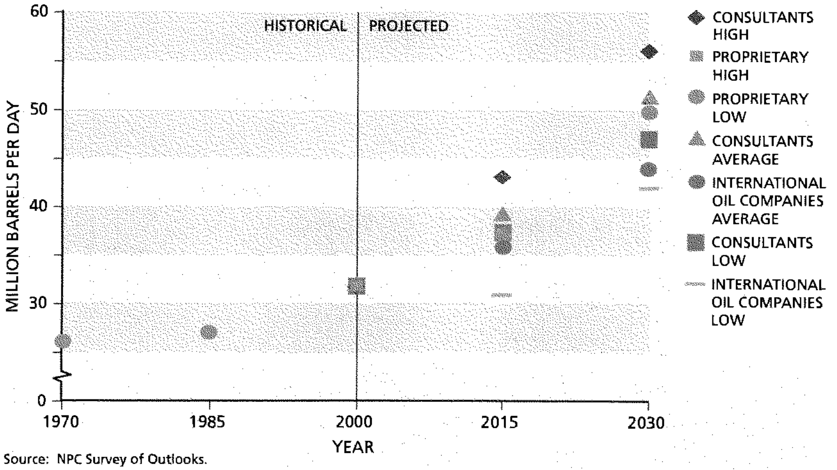
Note: IOC = International Oil Companies; CONS. = Consultants; and PROP. = Proprietary.
Source: NPC Survey of Outlooks.

FIGURE 2-29. *Canadian Total Liquids Production Outlook*



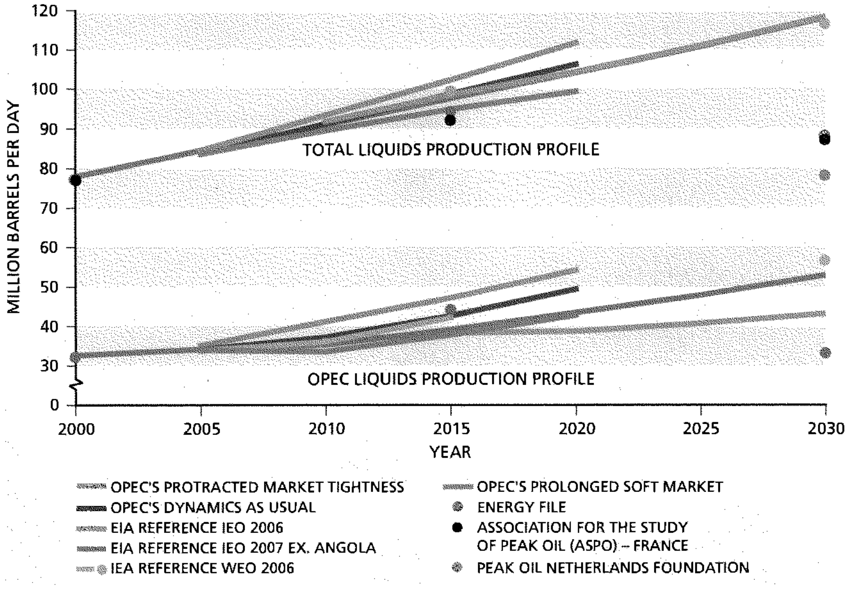
Source: NPC Survey of Outlooks.

FIGURE 2-30. *Projected OPEC Total Liquids Production*



Source: NPC Survey of Outlooks.

FIGURE 2-31. *Projected OPEC Total Liquids Production — Proprietary Aggregated Cases*



Source: NPC Survey of Outlooks.

FIGURE 2-32. *Projected Global and OPEC Total Liquids Production*

Unconventional Liquids Production

Unconventional liquids are projected to grow to about 10 percent of total liquids production by 2030 (Figure 2-36). The EIA IEO 2007 Reference Case shows total unconventional liquids production above 10 MB/D, with Canadian oil sands and Venezuelan heavy oil comprising the major part of the increase. Commercial considerations and the relative immaturity of production technologies for unconventional liquids lead to much uncertainty about the availability and timing of these fuels. Oil sands projects in Alberta will be pivotal to forecasted growth in Canadian total liquids production, if they overcome infrastructure, environmental, and cost challenges. While all forecasts expect growth, the range between them widens to 2 MB/D by 2030.

Most forecasts project that Venezuelan production will increase from 2005 levels. Venezuela's national oil company, Petroleos de Venezuela (PDVSA), projects the highest growth, expecting to more than double its total liquids production capacity to 5.8 MB/D by 2012.[6] The IEA forecast, which is lower than PDVSA's, expects new production from both extra-heavy oil projects in the Orinoco area and conventional oil fields. Forecasted production in 2015 compared to 2005 ranges from flat to an increase of 0.6 MB/D. Production in 2030 ranges from 0.5 to 2.3 MB/D more than in 2005. (Figure 2-37)

The EIA Reference Case expects the remaining increase in unconventional liquids production to come mainly from: biofuels derived from agricultural products (16 percent); gas-to-liquids (11 percent); and coal-to-liquids (23 percent). Indicative of this trend, the United States has announced a production goal for ethanol and other unconventional fuels of 2.3 MB/D by 2017, up from about 0.4 MB/D in 2006 and 0.5 MB/D in 2012.

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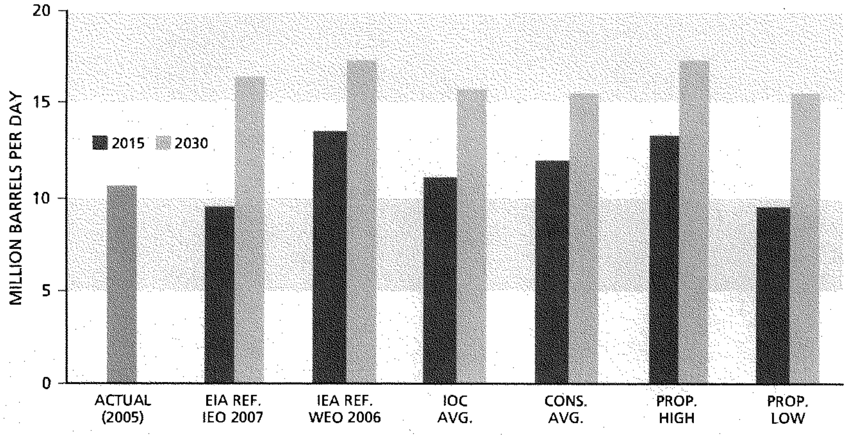
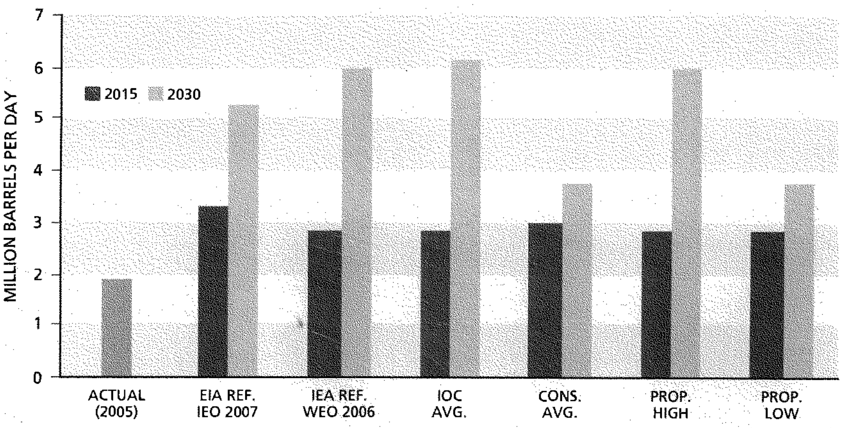
[6] http://www.pdvsa.com/index.php?tpl=interface.en/design/home.tpl.html



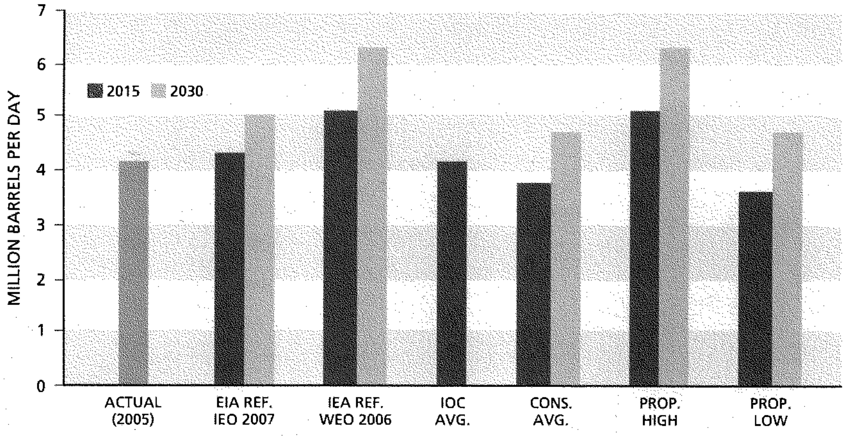
Note: IOC = International Oil Companies; CONS. = Consultants; and PROP. = Proprietary.
Source: NPC Survey of Outlooks.

FIGURE 2-33. Projected Saudi Arabian Total Liquids Production



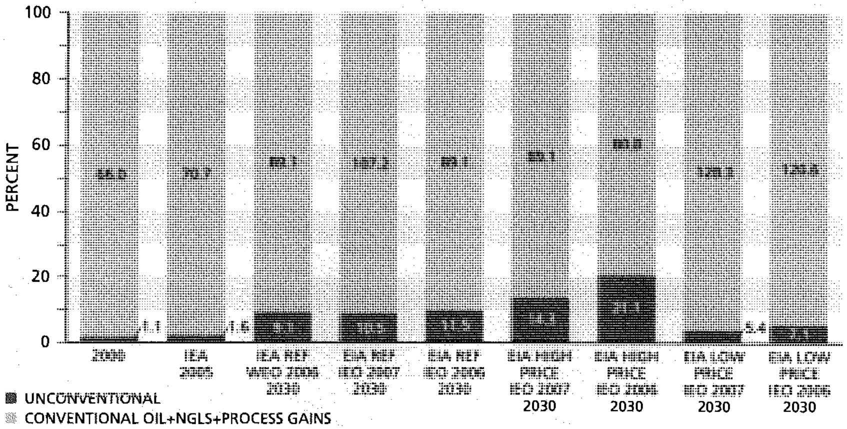
Note: IOC = International Oil Companies; CONS. = Consultants; and PROP. = Proprietary.
Source: NPC Survey of Outlooks.

FIGURE 2-34. Projected Iraqi Total Liquids Production



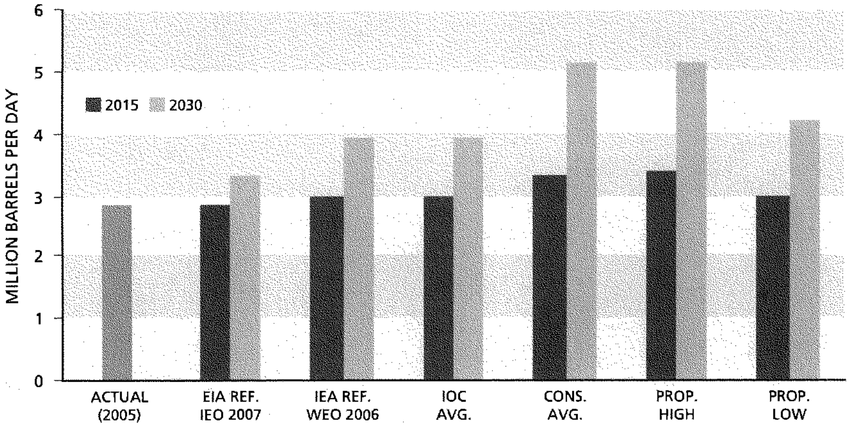
Note: IOC = International Oil Companies; CONS. = Consultants; and PROP. = Proprietary.
Source: NPC Survey of Outlooks.

FIGURE 2-35. Projected Iranian Total Liquids Production



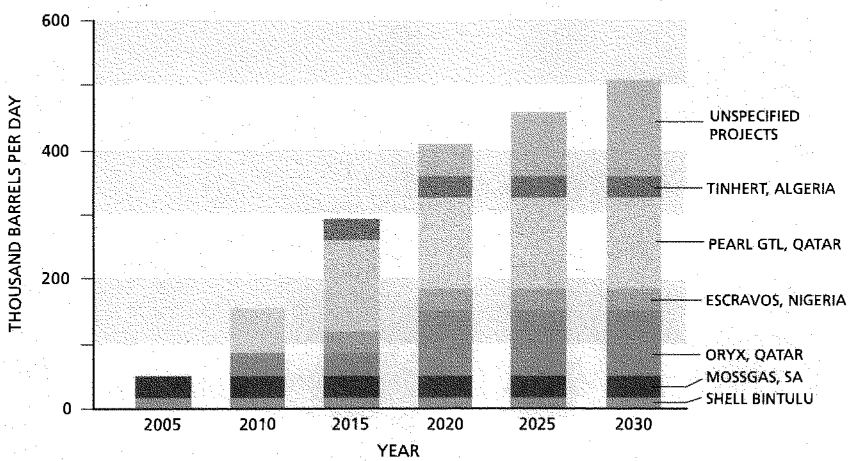
Note: Units shown in million barrels per day.
Source: NPC Survey of Outlooks.

FIGURE 2-36. Projected Global Conventional and Unconventional Total Liquids Production



Note: IOC = International Oil Companies; CONS. = Consultants; and PROP. = Proprietary.
Source: NPC Survey of Outlooks.

FIGURE 2-37. *Projected Venezuelan Total Liquids Production*



Source: NPC Survey of Outlooks.

FIGURE 2-38. *Projected Gas-to-Liquids Plant Capacity Based on Current Projects*

Production Source	Current Production Forecasts 2005-2030 (Million Barrels per Day)	Access	Investment	Infra-structure	People and Equipment	Environment	Geopolitics
Conventional Non-OPEC	35-75		X	X			X
Russia	10+	X	X	X			X
Conventional OPEC	30-55	X	X	X	X		X
Saudi Arabia	10-17+						
Unconventional Crude	1-10		X	X	X	X	
Heavy	1-10						
Shale Oil	<1						
Alternatives	1-5						
Biofuels	1-3		X	X	X		
Gas-to-Liquids	~1			X			
Coal-to-Liquids	~1		X			X	
Production Growth	**2005-2030 Expected Growth (Million Barrels per Day)**						
Saudi Arabia	+3-7		X		X		
Iraq	+4		X	X	X		X
Canada	+2			X	X		
Venezuela	+2	X	X	X	X		X
Nigeria	+2		X				X
Iran	1-2	X	X	X	X		X
Kuwait	1-2		X		X		
UAE	1-2		X		X		
Libya	1-2		X		X		

Note: An X in any column means that the matter is problematic or open to question for that resource type or country.

TABLE 2-3. *Oil Production Challenges*

GTL and CTL plants typically convert natural gas and coal to liquid fuels. The product is usually about 70 percent ultra-clean diesel fuel and 25 percent naphtha for chemical feedstock.

In the past ten years, several world-scale GTL plants have been developed or announced. However, given recent cost increases, several large projects (e.g., in Qatar) have been cancelled or postponed in 2006 and 2007. All forecasts received for the study project that GTL will grow quickly from a very low base, but not enough to significantly affect oil product or natural gas markets. Several estimates for GTL capacity growth show only 0.5 MB/D of GTL fuels being produced worldwide through 2030, mainly clean diesel and naphtha (Figure 2-38). In this event, GTL would provide only about 1 percent of global middle distillate fuel requirements. By comparison, EIA IEO 2007 shows stronger GTL production growth to 1.2 MB/D in 2030, with Qatar as the primary source. For further discussion, see the Gas-to-Liquids Topic Paper.

For a further discussion of coal-to-liquids, see the Coal section of this chapter and the Coal-to-Liquids Topic Paper on the CD that accompanies this report.

Oil Supply Challenges

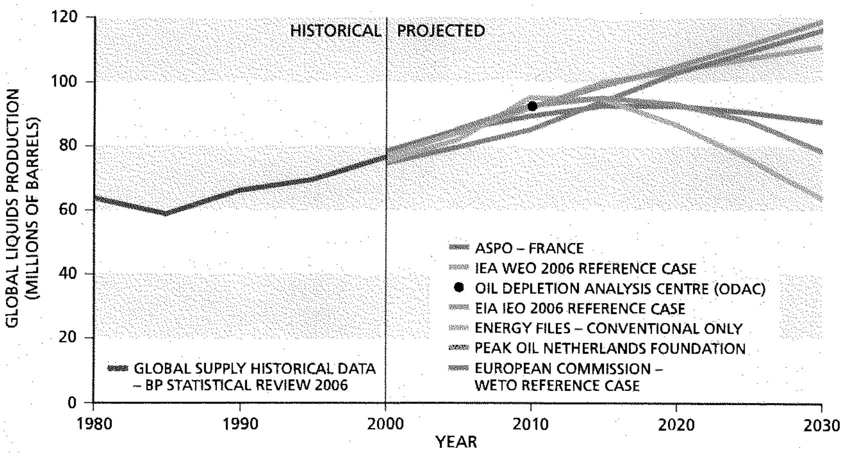
The forecasts and data received for this study lead to the conclusion that oil supply increasingly faces above-ground challenges in addition to geological and technical hurdles. The challenges include access, geopolitics, investment requirements, commercial and trade regimes, infrastructure, and workforce availability. Table 2-3 is a snapshot of above-ground challenges that affect the resource types and sources of projected oil supplies to 2030. The prospects are likely to be further complicated since the challenges change with place, resource, and time.

Peak Oil ◆

Concerns about the reliability of production forecasts and estimates of recoverable oil resources are the basis of warnings about future oil supplies and the deliverability of oil. The concerns are compounded by the challenges some companies face in adding new reserves to replace those already produced. The warnings are strongly expressed in a set of forecasts known collectively as *peak oil*. The term derives from the *Hubbert's Peak* analysis of U.S. oil production written by M. King Hubbert.

Peak oil forecasts project that oil supply will not grow significantly beyond current production levels and therefore may not keep pace with projected global demand; a peak and decline in oil production is inevitable and may be near-at-hand. The conclusions lead to calls to develop additional resources to increase supply, accelerate the use of unconventional resources as substitutes for oil, and moderate demand in order to bridge the forecast supply shortfalls. Such actions generally converge with the recommendations of this study.

The forecasts reviewed for this study that do not consider new policies such as carbon constraint show considerable agreement until 2015 (Figure 2-39). After 2015, views about supply trends diverge, with peak oil forecasts providing the lower bound. The divergent views of oil supply after 2015 fuel growing concern about the



Source: NPC Survey of Outlooks.

FIGURE 2-39. *Global Total Liquids Production — Reference Forecasts 2000-2030*

deliverability of the resource base and the uncertainty regarding timing and volume of future supplies.

Peak oil forecasts emphasize various physical limitations to raising production rates, including: reserve estimates that are lower than reference cases; limited future development opportunities; and insufficient volumes from unconventional production over the study time frame. These forecasts generally consider oil supply independently of demand and point to supply shortfalls. Such views contrast with forecasts and economic models that expect market forces to provide incentives for developing global hydrocarbon and other resources to meet fuel needs through at least 2030.

Peak oil forecasts use several indicators to support the case for an imminent peak in global production. One leading indicator is the difficulty of adding new reserves to make up for produced volumes, especially through exploration. However, companies and countries use different methods to estimate recoverable resources and what they term reserves. The lack of transparency and consistency in this reporting confuses the situation and is a concern in all forecasts.

A second indicator is the growing number of countries that show a historical peak in their oil production. Many forecasts rely on the shape of production curves in countries that have displayed a peak to extrapolate future production rates for that country and to develop forecasts for countries whose production has not peaked. The extrapolations are based on the observed physical behavior of most oilfields. This method raises considerable debate, since many factors affect production from a field, basin or country.

In the absence of production restrictions, oil production from a well usually declines from its initial levels. As other wells are incorporated in a field, oil production rises to a given rate at the field level and then declines. Production costs generally increase throughout the development of the field as the productivity of wells decreases. This well and field production profile is often extrapolated to represent producing basins, countries and the world. If a fixed or slowly growing resource base is also assumed, forecasted global production would inevitably follow a similar pattern of decline.

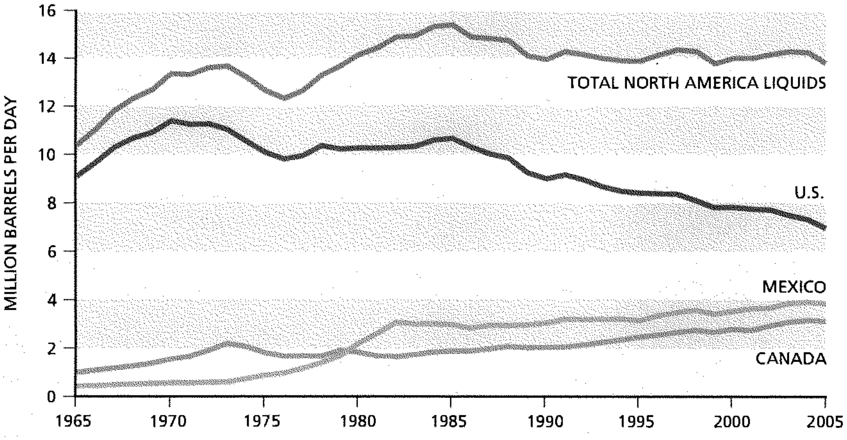
Peak oil forecasts point to the importance and dominance of large fields, since they have produced most of the world's oil. In general, large fields are among the first to be found, and have economically attractive scales and production costs. Production from such large reservoirs is usually considered conventional oil that did not require technology to stimulate oil flow during the early stages of production.

Views of an impending peak in liquids production are usually countered by expectations for new discoveries, additions to the resource base, new technologies, and greater operating experience that change the production profile of new and existing producing fields. Production rates are not fixed and can be influenced by these and other factors such as costs and price.

Peak oil forecasts are concerned about the ability to extend and apply experience from mature areas to less produced areas. As a hydrocarbon province matures, production transitions from large reservoirs to smaller, less prolific, and possibly higher-cost reservoirs. In the United States, for example, production from smaller and mature reservoirs dominates supplies. Peak oil forecasts assume that remaining smaller reservoirs will not compensate for declines in the larger reservoirs, resulting in declining conventional oil production in the near future. However, the North Sea has seen the evolution away from larger, depleted fields to smaller fields that can be brought online using existing infrastructure. North Sea production has actually been sustained for many years at significantly higher levels than was generally thought likely in the 1980s and early 1990s. Production growth from 1990 to 2000 shows how production in mature basins can revive as a result of new technology, price, or market dynamics.

As conventional oil development moves to smaller reservoirs in regions where access remains feasible, the industry is increasingly turning to frontier resources, deep and ultra-deepwater fields, and unconventional very heavy and sour fields. New developments include the Alaskan Arctic, deepwater Gulf of Mexico, offshore West Africa and Brazil, and Alberta oil sands. Frontier and unconventional resources in North America have compensated for declines in United States oil production, keeping total liquids production nearly flat over the last 15 years (Figure 2-40). This view of sustained North American production is challenged by expected and announced decreases in production from the Cantarell field in Mexico, the fourth largest producer in the world and source of most of Mexico's production in recent decades. Peak oil forecasts argue that development of smaller reservoirs will not be able to reverse Mexico's decline.

Although production growth from frontier and unconventional resources will require long lead times



Source: *BP Statistical Review 2006.*

FIGURE 2-40. *North American Liquids Production*

and very large investments, there is considerable agreement about continued growth in the supply of unconventional oil and alternative liquids. However, peak oil forecasts do not see these resources as offsetting declines in existing conventional oil production.

A country's oil production profiles are the sum of the production profiles of the fields in that country, just as fields are the sum of profiles of individual wells. The overall decline rate of a field is a combination of the decline from existing wells and the production volumes from new wells. In addition, changes in production technology and the use of enhanced recovery techniques can reduce expected declines.

Figure 2-41 shows typical production profiles as they evolve over time. The curves can apply at different scales from individual oil wells to fields, countries, or larger regions. Wells and fields vary in their stage of development: some may be declining, some at a production plateau, while others may be ramping up production. The global production profile is the aggregate of the profiles from all individual fields with diverse profiles.

While most fields have production profiles shaped like Part A of Figure 2-41, many have other more

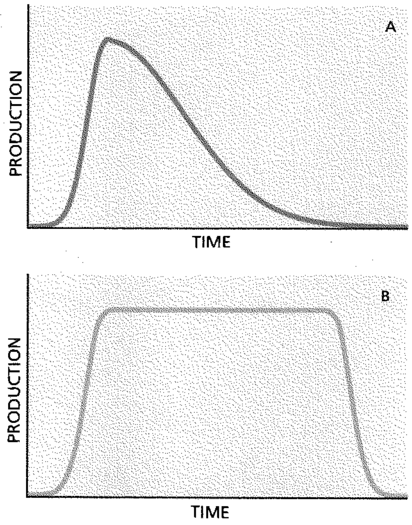


FIGURE 2-41. *Typical Oil Production Profiles*

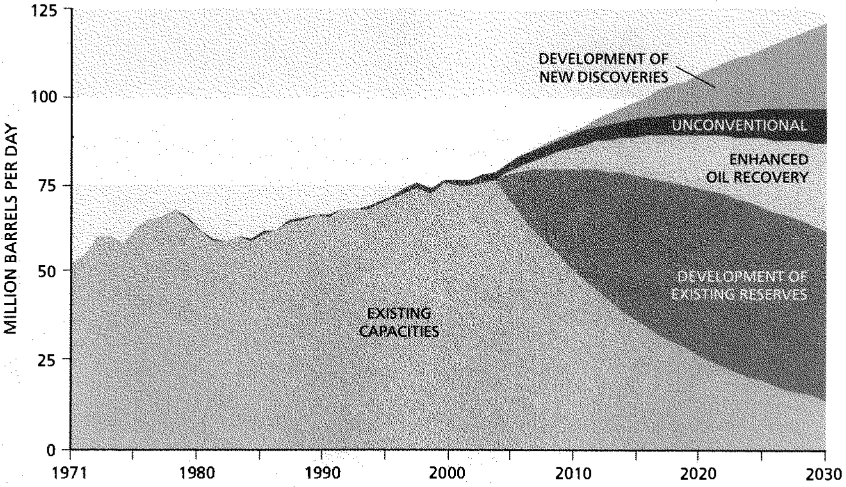
general profiles. For example, where downstream bottlenecks constrain production, the profile may plateau as in Part B. Historically, technology advances have increased the recovery factors, or percent of resources, recovered from a reservoir. Technical advances, such as enhanced oil recovery (EOR), will continue to improve recovery factors and thus modify production profiles for individual wells and fields. For a complete discussion of production profiles and potential technology effects, see the Conventional Oil section in the Technology chapter of this report.

Figure 2-41 is illustrative. It demonstrates that managing the shape and duration of the production profile is a central issue not only in the peak oil debate but in all prospects for oil supply.

Investment

The IEA WEO 2006 Reference Case estimates that the global oil industry will need a total investment of about $4.3 trillion between 2005 and 2030, or about $164 billion annually, to meet projected demand. Most of the projected investment will be in the upstream sector, largely devoted to maintaining existing production capacity. The IEA investment figure is substantially higher than prior years, partly based on sharp increases in unit capital costs. Other causes for the higher projection include the cost of developing remote, technically challenging, or deeper reservoirs, or oil in smaller accumulations. Additional capital will be needed to minimize production declines at the world's largest, aging fields. A recent OPEC study showing strong correlation between exploration and production (E&P) investment and oil production rates suggests that projected capital requirements are likely to increase.

Much of the world's existing oil production will need to be replaced by 2030. Figure 2-42 is an illustrative example of the various resource components that contribute to total liquids supply. These components contribute to virtually all liquids supply projections, although the combination and timing of the components may differ. Maintaining current oil supply levels will require slightly more than half the $4.3 trillion



Source: IEA, *World Energy Outlook 2004.*

FIGURE 2-42. *Illustrative Total Liquids Supply*

investment. The remaining investment will be needed to expand supply to meet projected demand and build or replace infrastructure. Financing this investment is likely to be a major undertaking, with enormous requirements in individual countries and regions. For example, projected investment in China alone is about $350 billion, or half the total for Middle Eastern countries. Of the total global investment, more than half is expected to be in developing countries.

Geopolitics

Oil is currently a fungible commodity traded in global markets. Changes in oil trading patterns are expected during the study's time frame, based on evolving relationships between importing and exporting countries and regions. Global redistribution of infrastructure and manufacturing capability will also change commodity and product trade flows. These changes are likely to bave important and uncertain geopolitical dimensions. For example, the IEA reports that OECD countries imported 17.9 million MB/D from OPEC producers in 2003, or 57 percent of OPEC's petroleum exports. The IEA Reference Case shows these exports rising by 3.2 MB/D at the end of the study time frame, with slightly more than 40 percent of the increase supplied from the Persian Gulf. The projection assumes that the existing OECD-OPEC trading relationship can be reliably extrapolated. If this is not case, the availability of supply becomes a more uncertain and pressing issue. Such geopolitical factors apply to all energy forecasts and are fully addressed in the Geopolitics chapter of tbis report.

Natural Gas

Key Observations—Natural Gas

- *Most forecasts project that global natural gas production will grow rapidly to meet increasing demand.*
- *Current estimates of recoverable natural gas resources are sufficient to sustain the large, anticipated increase in production over the study time frame, providing above-ground issues and challenges do not become major constraints.*
- *As gas production in OECD countries lags demand growth, these demand centers will require major additional infrastructure to ensure delivery by pipeline and liquefied natural gas (LNG).*
- *Growth in global natural gas trade is expected to occur at a faster pace than historically, with the largest new supply volumes originating in Russia and the Middle East.*
- *Additions to LNG supply capacity are capital intensive, complex, and face development uncertainty. Growing risks in the investment climate for LNG and for long-distance natural gas pipelines may delay or reduce supply availability.*
- *North American and U.S. natural gas production is likely to lag projected demand growth over the study time frame, requiring significant growth in LNG imports. The wide range of projected U.S. LNG import requirements raises uncertainty about whether these requirements will be met, particularly at the higher estimates.*
- *Unconventional natural gas is expected to make up an increasingly important share of U.S. gas production*
- *Development of Arctic natural gas resources, both in the United States and Canada, could contribute significantly to North American gas supply if major infrastructure is developed*
- *Increased access to restricted and moratoria areas on U.S. offshore and onshore public lands could increase natural gas supplies available to the United States.*
- *Natural gas demand in a carbon-constrained world is likely to be significantly higher than in a business-as-usual future, increasing the importance of timely supply and infrastructure development.*

Global Natural Gas Endowment and Technically Recoverable Resources

In 2000, the USGS estimated tbat remaining recoverable conventional gas resources totaled about 12,000 trillion cubic feet (TCF). This is the mean estimate in a range from 8,000 to 19,000 TCF. This gas volume is equivalent to about 2 trillion barrels of oil, or double the total amount of oil produced globally to date. Many gas supply forecasts base their projections on the USGS estimate, which is somewhat higher than proprietary estimates aggregated for this study. For example, the IOC aggregated mean for total recoverable resources is 12,000 TCF, with a range of 11,300 to 13,900 TCF. The IOC range for remaining recoverable resources is 8,000 to 12,000 TCF, with a mean of 10,300 TCF. The USGS recoverable resource assessments do not include unconventional gas, which may represent a significant addition to gas supplies over the next 25 years. Similarly, the assessments do not include natural gas hydrates, a potentially significant resource that is not currently considered technically recoverable and is unlikely to be developed over the study time frame.

About 3,000 TCF of natural gas has already been produced (Figure 2-43). The projected supply of natural gas to 2030 ranges from 3,100 to 3,650 TCF. Thus, current mid-range estimates of conventional, global, technically recoverable resources are considerably greater than combined historical and projected production. Indeed, mid-range projections expect less than 50 percent of USGS-estimated conventional gas reserves to be produced by 2030. If IOC mean or low-range estimates prove more accurate, global gas production will exceed 50 percent of the technically recoverable resource by 2030. Whether or not global natural gas production reaches a plateau during the study time frame, the possibility becomes greater within the next 50 years, unless a major technical breakthrough allows economic production of significant volumes of unconventional gas and gas hydrates.

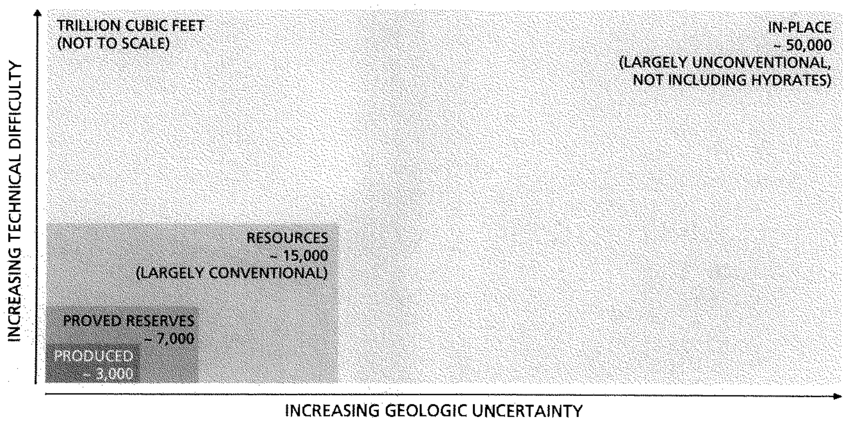
Nearly 83 percent of technically recoverable natural gas resources are in the Middle East, Non-OECD Europe, Asia/Oceania, and Africa (Figure 2-44). The overall distribution of resources is becoming more remote from major natural gas markets, with the exception of Russia, a major gas consumer as well as resource holder.

Current proved reserves of natural gas are concentrated in a few countries, with Russia, Iran, Qatar, and Saudi Arabia comprising more than two-thirds of the global total (Figure 2-45). Of the 12 largest resource owners, 11 are outside the OECD, comprising more than 75 percent of global gas reserves. Such concentration raises issues about risks and the costs of developing and producing the reserves to meet growing gas demand.

U.S. Technically Recoverable Gas Resource

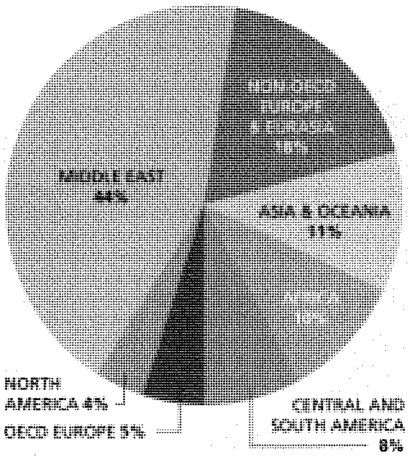
The 2003 NPC study, *Balancing Natural Gas Policy*, estimated that about 1,450 TCF of technically recoverable resource remain in the United States. Technical advances may add an additional 400 to 500 TCF by 2030 (Table 2-4).

The technically recoverable domestic gas resource is subject to numerous restrictions. About 162 TCF of the U.S. onshore recoverable natural gas resources



Sources: U.S. Geological Survey, 2000; and Rogner, H-H., "An Assessment of World Hydrocarbon Resources," Institute for Integrated Energy Systems, University of Victoria, 1997.

FIGURE 2-43. *Global Natural Gas Endowment*

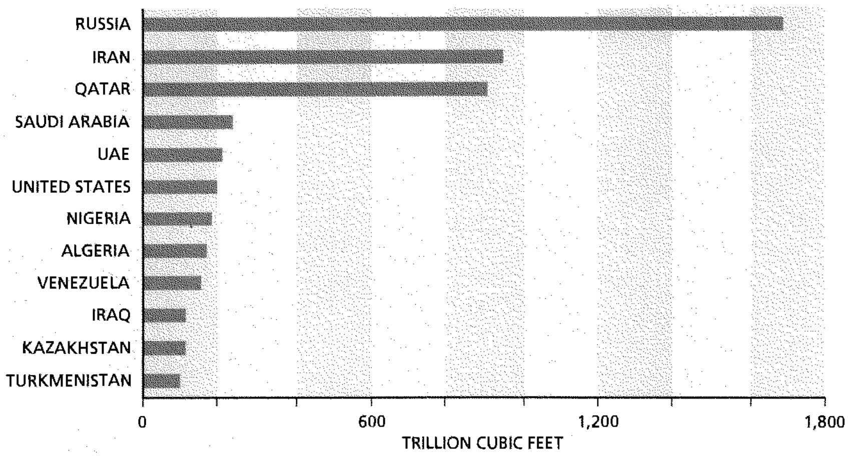


Source: U.S. Geological Survey, 2000.

FIGURE 2-44. *USGS Estimated Natural Gas Resource Shares, 2000*

lie beneath federal lands that are restricted beyond standard lease terms or are entirely off limits. This estimate was developed by government studies conducted in accordance with the U.S. Energy Policy and Conservation Act of 2000 and the Energy Policy Act of 2005. The restricted areas range from Alaska to the Rockies, the Gulf Coast, and Appalachia. Approximately 92 TCF of U.S. offshore technically recoverable natural gas resources are also currently off limits for leasing and development. Of these, almost 86 TCF of natural gas are in the federal U.S. Outer Continental Shelf (OCS) moratoria areas (Table 2-5). Resource estimates for all restricted areas are very uncertain, since the last seismic data acquisition or drilling in some cases occurred 25 to 40 years ago.

In aggregate, access is restricted to 76 percent of U.S. technically recoverable natural gas resources. About 66 percent of domestic resources (882 TCF) are on state, tribal, and private lands, predominantly in onshore tight gas and shale formations. The technical challenges to developing domestic gas resources are compounded by urban growth, competing land use, and changing public values that increasingly constrain existing and new natural gas development.



Source: *BP Statistical Review of World Energy 2006.*

FIGURE 2-45. *Largest Natural Gas Reserve Holders, 2005*

	Current Technology	2015 Technology	2030 Technology
Lower-48 Onshore	764	839	1,026
Lower-48 Offshore	384	415	498
Alaska	303	331	356
Total U.S.	1,451	1,585	1,687

Source: National Petroleum Council, *Balancing Natural Gas Policy*, 2003.

TABLE 2-4. *U.S. Natural Gas Resource Base (Trillion Cubic Feet)*

Moratoria Areas	Resources
Gulf of Mexico	22
Alaska	9
Atlantic	37
Pacific	18
U.S. Federal OCS	**86**
Great Lakes	5
State Waters	1

Sources: Department of the Interior (MMS and USGS) and Interstate Oil and Gas Compact Commission.

TABLE 2-5. *U.S. Offshore Natural Gas Resources in Moratoria Areas (Trillion Cubic Feet)*

The United States has almost 290,000 marginal gas wells.[7] In 2005, marginal wells accounted for 1.7 TCF of natural gas per day, or more than 9 percent of domestic onshore production. Increasing operational and regulatory costs and diminishing pipeline access to markets may contribute to premature abandonment of these wells and loss of gas production. When marginal wells and fields are prematurely abandoned, the associated oil and gas resources may never be recovered due to economics, lease termination, and related issues—thus widening the gap between projected gas demand and domestic supply.

Global Natural Gas Production

Global gas production to 2030 is forecast to grow faster than the historical rate since 1980 of about 50 billion cubic feet per day per decade. The EIA and IEA 2006 Reference Cases project growth rates of 2.4 percent and 2.0 percent, respectively. Both rates are higher than the growth rates for coal and oil over the study time frame (Figure 2-46).

The proprietary forecasts aggregated for the study show average gas production of about 450 billion cubic feet per day in 2030, a value very similar to the IEA Reference Case. The upper and lower limits are approximately 425 and 500 billion cubic feet per day (Figure 2-47).

The highest projected natural gas production in 2030 is 530 billion cubic feet per day. This forecast requires a high supply of gas to balance energy demand, since it also projects that oil production in 2030 will be below today's level (Figure 2-48). Most Alternative Policy cases in Figure 2-48 also project gas production above 400 billion cubic feet per day, as the energy mix increasingly favors lower carbon fuels that reduce carbon dioxide emission levels.

Regional Supply Patterns

Regional supply patterns for natural gas are shifting. Forecasts show that production and exports from the Middle East, Non-OECD Europe (Russia), and Asia (Australia) will increase substantially over the next 25 years, although in total Asia will probably remain a net importer of natural gas (Figure 2-49). The United States and OECD Europe are likely to increase their dependence on gas imports, since most projections show continued growth in demand but flat or declining production in these regions.

Most growth in natural gas production is expected to occur in exporting countries. Transporting the gas to consuming regions will require substantially increased investment in production and transportation infrastructure, particularly:

- Liquefaction plants in producing countries and regasification terminals in consuming countries for LNG.
- Long-distance, high-capacity natural gas pipelines.

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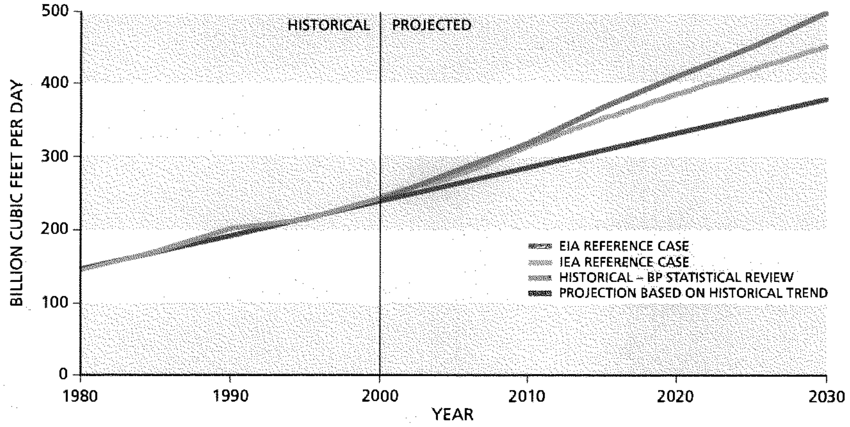
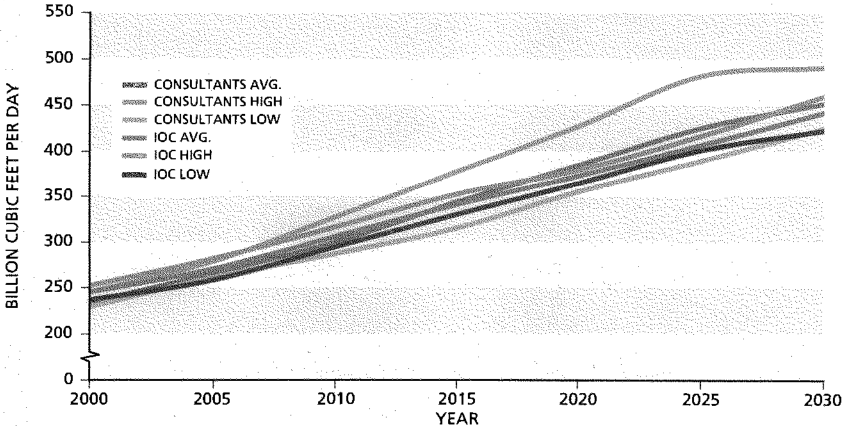
[7] Interstate Oil and Gas Compact Commission (IOGCC), *Marginal Wells: Fuel for Economic Growth* (2006). The IOGCC defines marginal wells as those producing 60 thousand cubic feet or less of natural gas per day. The Internal Revenue Service defines marginal wells as producing 75 thousand cubic feet or less of natural gas per day.



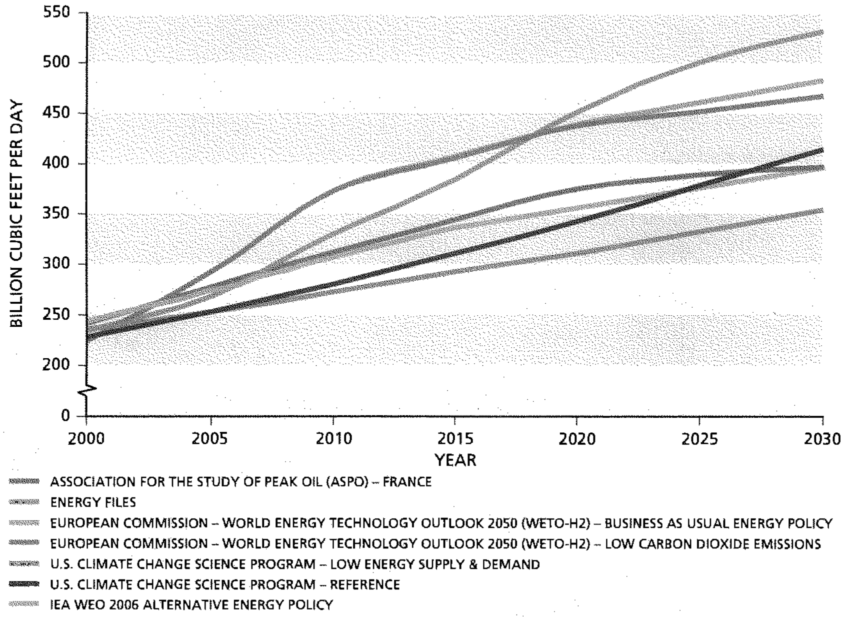
Sources: Energy Information Administration (EIA), *International Energy Outlook 2006;* International Energy Agency (IEA), *World Energy Outlook 2006;* and *BP Statistical Review of World Energy 2006.*

FIGURE 2-46. *Projected Global Natural Gas Production*



Note: IOC = International Oil Companies.
Source: NPC Survey of Outlooks.

FIGURE 2-47. *Projected Global Natural Gas Production — Proprietary Aggregated Data*



Source: NPC Survey of Outlooks.

FIGURE 2-48. *Projected Global Natural Gas Production — Public Data*

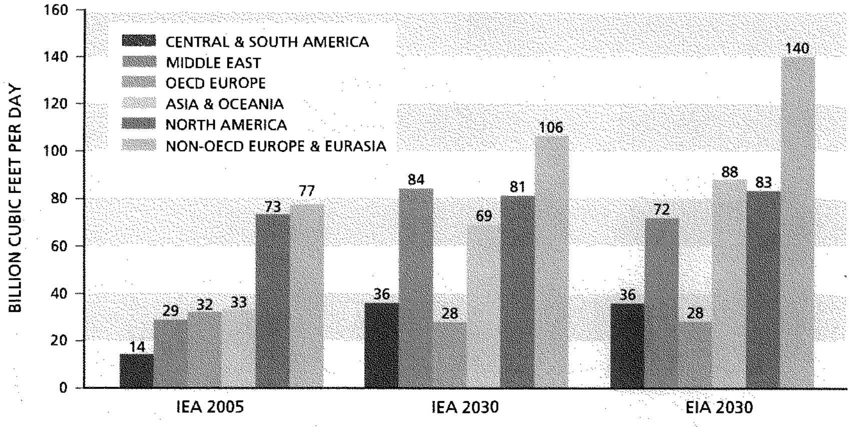
Figures 2-50, 2-51, and 2-52 show the increasing importance of imports in the main OECD demand regions that were traditionally supplied from indigenous sources. Domestic supply in North America is expected to decline and then, possibly, to reach a plateau as unconventional resources (e.g., tight gas, coalbed methane, and shale gas) supplement domestic conventional gas production. Most forecasts assume that pipeline supplies from Alaska and the Mackenzie Delta will reach North American markets in the study time frame. However, projected demand growth will ultimately be met by increasing LNG imports.

Domestic production in Europe is expected to be flat or declining, with pipeline imports increasing dramatically, primarily from Russia and the Caspian region. LNG imports will also play a growing and more significant role in meeting Europe's gas requirements.

Unlike other major consuming areas, Asia Pacific is expected to see a significant increase in domestic production of natural gas. Much of this growth will be traded between producing countries such as Indonesia and Australia and consuming countries such as Japan and China. The region will also need greater supplies of LNG to meet about 30 percent of projected regional demand. Long-distance gas pipelines to Russian, Caspian, and Middle East supplies are also a potential option.

North American Gas Production

Natural gas production in the United States has been relatively flat over the past 35 years, while



Sources: International Energy Agency (IEA), *World Energy Outlook 2006;* and Energy Information Administration (EIA), *International Energy Outlook 2006.*

FIGURE 2-49. *Projected Regional Natural Gas Production (Regional Data)*

demand has been growing over most of that period (Figure 2-53). Since the mid-1980s, most of the growing gap between domestic production and consumption has been filled by increased gas pipeline imports from Canada. Since 2003, LNG imports from several other countries have also grown, making a small but increasingly important contribution to U.S. gas supply.

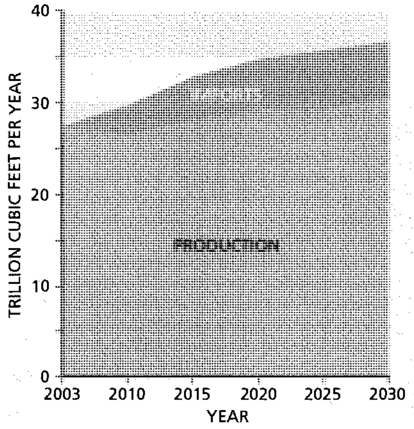
For North America as a whole, natural gas production has been largely sufficient to meet demand over the past 35 years (Figure 2-54). Growing integration of the pipeline systems of Canada, the United States and Mexico has allowed regional trade flows to develop and balance the gas markets in each of the countries. Beginning in 2004, the region has imported larger quantities of LNG, with the LNG contribution reaching about 2 percent of North American supply by 2006.

EIA projections show some potential for maintaining a slow growth rate in North American natural gas production (Figure 2-55). The IEA concurs with this outlook, also projecting a North American natural gas production growth of about 0.4 percent per year. Both forecasts assume growing success in exploiting unconventional natural gas resources in North America and completion of two major pipelines to bring Arctic gas to market centers from Alaska and the Mackenzie Delta. The risks and challenges associated with these potential supply sources are discussed below.

Over the next 25 years, it will be an increasing challenge to avoid declining conventional gas production rates in the United States. The 2003 NPC natural gas study identified such contributing factors as accelerating decline rates, decreasing size of new conventional discoveries, and higher finding and development costs for deeper and more technically challenging gas accumulations.

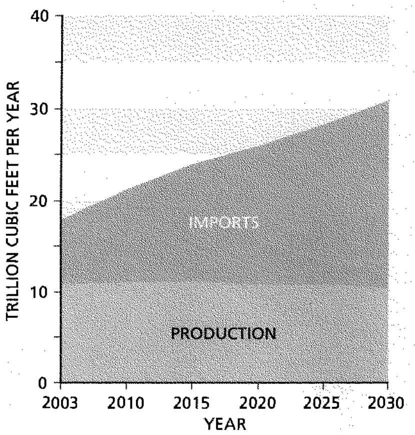
The forecasts analyzed for the current study largely agree that domestic conventional gas production will decline over the forecast period, assuming that restricted onshore and offshore areas will not be developed. The balance of natural gas supply to the United States over the next 25 years is generally expected to be met by a combination of three elements:

- Increased domestic production of unconventional gas (basin-centered gas, tight gas, shale gas, coalbed methane)



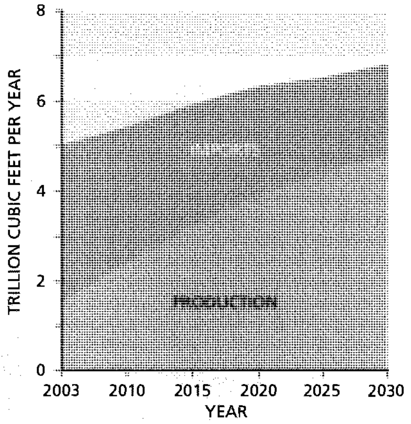
Source: Energy Information Administration, *International Energy Outlook 2006.*

FIGURE 2-50. *North American Natural Gas Production and Imports*



Source: Energy Information Administration, *International Energy Outlook 2006.*

FIGURE 2-51. *OECD Europe Natural Gas Production and Imports*



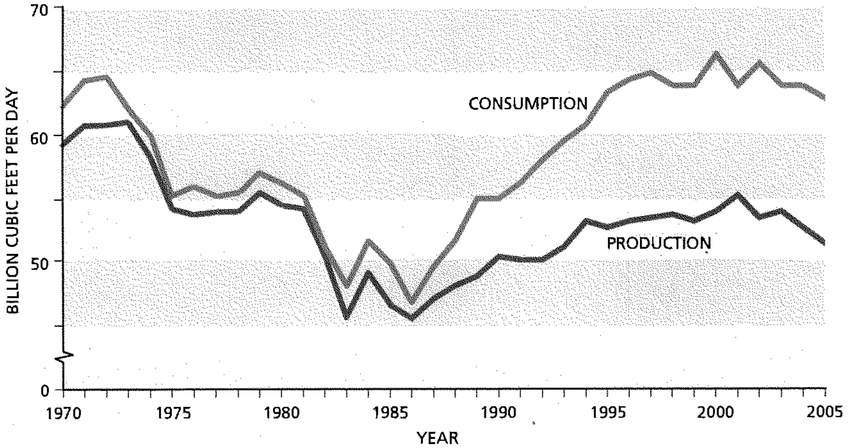
Source: Energy Information Administration, *International Energy Outlook 2006.*

FIGURE 2-52. *OECD Asia Natural Gas Production and Imports*

- Arctic gas resources from Alaska and the Canadian Mackenzie Delta, both of which require development and massive new infrastructure to bring gas to market
- Increased LNG imports.

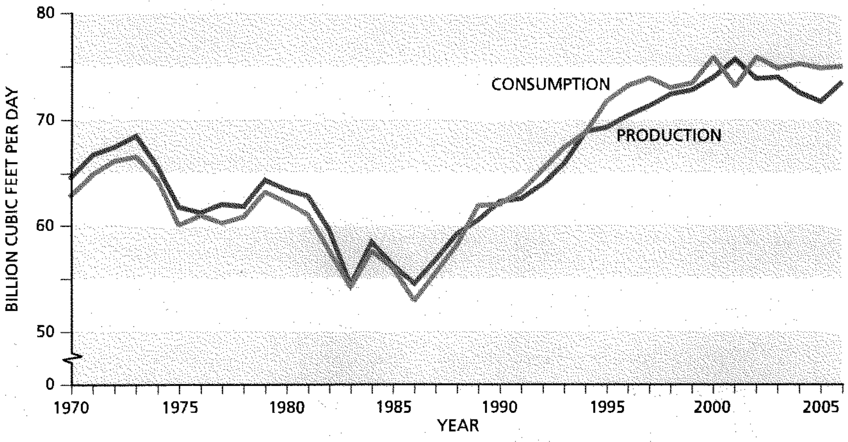
Each of these elements may be subject to risks that make development slower or less significant than the forecasts assume.

Unconventional gas typically costs more to develop than conventional gas, requires different production technologies, has a different environmental impact, and produces at lower rates. Therefore, maintaining or increasing investment in unconventional gas will be essential to growing supply. In addition, many unconventional gas resource basins are located in areas at some distance from demand centers. For example, the Rocky Mountain and San Juan basin regions contain very significant resources of tight gas, coalbed methane, and basin-centered gas. Growth in production capacity in these regions proportionate to the resource size will require new pipeline capacity to bring the gas to markets in the Midwest, Northeast, and West Coast.



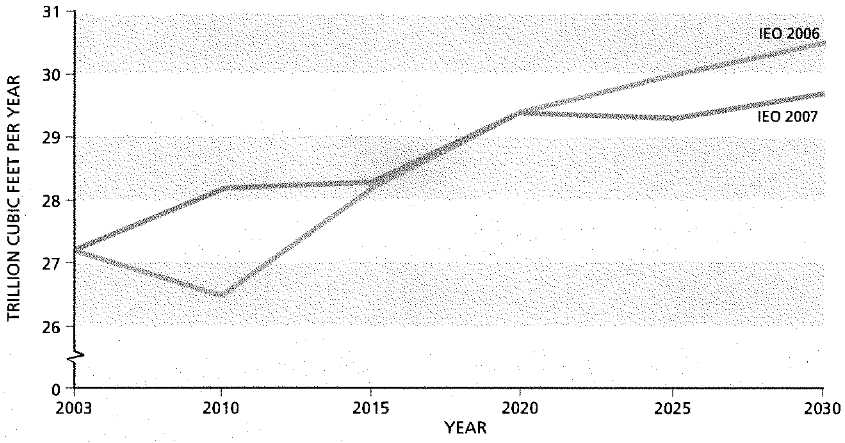
Source: *BP Statistical Review of World Energy 2006.*

FIGURE 2-53. *U.S. Natural Gas Production and Consumption, 1970-2005*



Source: *BP Statistical Review of World Energy 2006.*

FIGURE 2-54. *North American Natural Gas Production and Consumption, 1970-2005*



Source: Energy Information Administration, *International Energy Outlook 2006* and *2007*.

FIGURE 2-55. *Projected North American Natural Gas Production*

Most forecasts assume that Arctic gas from the United States and Canada will contribute significant volumes to North American supply, perhaps 6 to 8 billion cubic feet per day by around 2020. Huge stranded gas resources exist in the Arctic regions, but bringing gas to markets will require construction of new high-capacity, long-distance pipelines through Arctic terrain. Companies and agencies involved in proposed development of these pipelines have thus far not resolved complex issues involving regulatory frameworks, fiscal regimes, local communities, and environmental impacts. The investment required for these pipeline projects is huge, amounting to tens of billions of dollars. If the issues cannot be resolved, there is a significant risk that the investments may not be made in the timeframe of this study. If Arctic gas is not developed, North America and the United States would require significantly higher LNG imports.

Gas Supply Challenges

Considerable uncertainty surrounds the growth of natural gas production from mature areas as well as the timing of new projects in specific countries and regions. Table 2-6 summarizes various challenges that may constrain gas production. They include restricted access to resources; uncertain investment and fiscal frameworks; requirements for high-capacity, long-distance infrastructure; shortages of skilled people; escalating costs and possible shortages of vital equipment; geopolitical tensions; development policies of major gas resource holders; and the time required to develop and deploy new technology. The challenges are dynamic and will have different combinations in time and place over the time frame of the study.

Considering investment alone, the IEA WEO 2006 Reference Case estimates that the required investment in natural gas supply will amount to $3.9 trillion over the next 25 years. This figure includes large capital investments in Russia, Qatar, Iran, Nigeria, and Australia to increase exports.

Russia, the largest regional supplier to Europe, will be challenged to meet European demand growth while initiating exports to Asia and supplying its large and growing domestic market. The IEA projects that the Middle East and Africa will provide more than two-thirds of global inter-regional exports. At the same time, the Middle East will see increased

		Access	Investment	Infra-structure	People and Equipment	Geopolitics
Large Producers	Current Production (Billion Cubic Feet per Day)					
Russia	~100	X		X		X
United States	~50	X	X	X		
Indonesia	~10		X			
Production Growth	2005-2030 Expected Growth (Billion Cubic Feet per Day)					
Russia	+ 30	X		X		X
Qatar	+ 15				X	
Iran	+ 15	X	X	X	X	X
Nigeria	+ 10		X			
Australia	+ 10		X			

Note: An X in any column means that the matter is problematic or open to question.

Source: NPC Survey of Outlooks.

TABLE 2-6. *Natural Gas Supply Challenges*

domestic demand. It will also need natural gas to maintain pressure or enhance recovery in its oil fields.

Liquefied Natural Gas (LNG)

Key Observations—LNG

- *LNG trade is projected to grow faster than historical or future global gas and energy demand.*
- *The natural gas reserve base can support the projected expansion of LNG supply over the next 25 years.*
- *The global LNG market has many new entrants.*
- *Major uncertainties surround the scope and pace of liquefaction development in key supply countries.*

This section summarizes a full discussion in the LNG Topic Paper included on the CD distributed with this study.

Liquefied natural gas is a means of delivering natural gas from the wellhead to the market. Cooling the gas to such low temperatures that it converts to liquid reduces its volume, making it economical for transport over long distances by specialized ship. Since natural gas is in many cases too far from markets to be economically or practically transported by pipeline, liquefaction provides a way to link remote gas to markets.

Despite its rapid growth in recent years, LNG remains a relatively small contributor to total internationally traded gas. It comprises about 22 percent of the total gas trade and supplies only 7 percent of global gas demand. Pipeline gas still dominates international trade, notably supply to Western Europe from Russia, North Africa and Norway, and supply to the United States from Canada. By region, LNG trade in the Pacific Basin and Asian markets is almost double the size of Atlantic Basin and Mediterranean markets. However, the Atlantic Basin market has grown much faster than the Pacific market over the past ten years, growing by 12 percent per year compared to 5.5 percent per year in the Pacific market.

Global LNG Forecasts

All forecasts agree that global LNG growth is very likely to accelerate over the next 25 years. In the IEA WEO 2006 Reference Case, LNG trade grows by 6.6 percent per year between 2004 and 2030, from around 9 billion cubic feet per day to 46 billion cubic feet per day. The expected LNG contribution grows more than three times faster than a projected 2 percent per year increase in world natural gas demand. The IEA also projects that LNG will account for 70 percent of the increase in gas trade by 2030. LNG would then comprise half the internationally traded gas by 2030, compared to around 22 percent in 2004. The IEA identified key trends in the changing pattern of LNG supply:

- The Middle East and Africa account for over 70 percent of the increase in gas exports by 2030, mainly to supply Europe and North America.
- Russia will begin supplying gas to Asian markets by LNG.
- Australia and the Middle East will supply LNG to China.
- Venezuela is projected to emerge as an important supplier to North America and Europe.

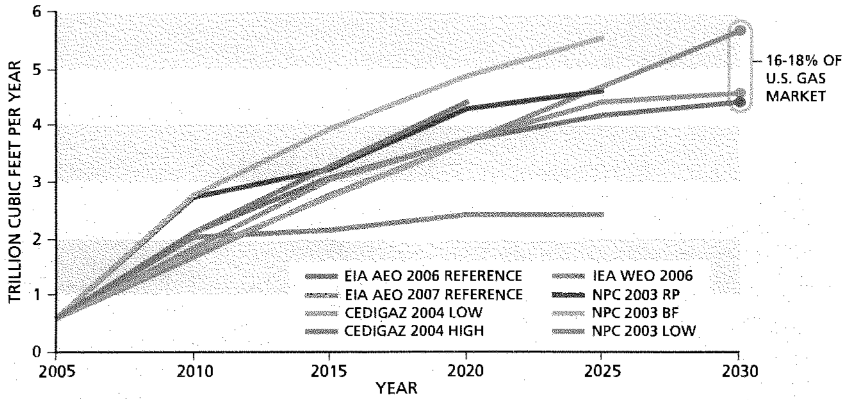
The EIA IEO 2006 provides a less detailed view of LNG developments to 2030. Discussion of LNG and gas trade developments in this outlook includes the following main points:

- Increasing concentration of natural gas reserves in Russia and the Middle East make these regions the most likely sources of supply growth.
- African natural gas production is expected to grow strongly through 2030, mainly for exports.
- Central and South America will have a surplus of gas, with Peru and Venezuela potentially joining Trinidad as LNG exporters.
- Russia, Norway, Equatorial Guinea, and Peru are likely to be new LNG exporting countries over this period.
- China, Canada, Mexico, Germany, Poland, Croatia, Singapore, and Chile are potential new LNG importing countries.
- The reliance of OECD countries on gas supplies from other regions will increase from 22 percent in 2003 to over 33 percent in 2030.

U.S. LNG Forecasts

Figure 2-56 shows projected LNG imports to the United States over the next 25 years. Depending on the forecast, LNG grows from about 2.5 percent of U.S. supply to 16 to 18 percent by 2030.

The EIA Annual Energy Outlooks provide a detailed look at factors specific to the U.S. gas market that may drive growth. The 2006 and 2007 Reference Case projections for LNG imports to the United States are similar. The main difference between the forecasts is that the



Note: RP = Reactive Path scenario; BF = Balanced Future scenario.
Sources: Energy Information Administration (EIA), *Annual Energy Outlook 2006* and *2007*; Cedigaz, *LNG Trade and Infrastructures*, February 2004; International Energy Agency (IEA), *World Energy Outlook 2006*; and National Petroleum Council (NPC), *Balancing Natural Gas Policy*, September 2003.

FIGURE 2-56. *Projected U.S. LNG Imports*

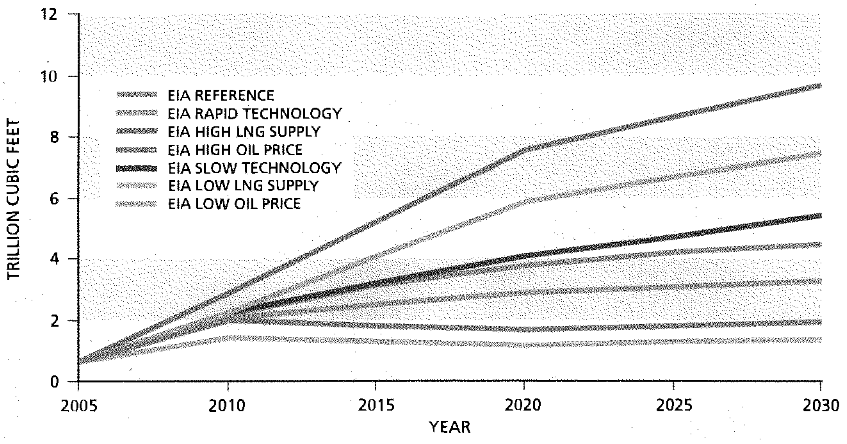
2007 update is slightly lower in the early years, because of slower development of upstream LNG projects, and slightly higher in the later years, especially after 2020.

The EIA AEO 2006 Reference Case projects that U.S. LNG imports will grow by 8 percent per year to 2030. Two factors drive the rapid increase: (1) a domestic gas production profile that begins to decline after 2020 and only increases by 0.5 percent per year over the entire period to 2030; and (2) pipeline imports from Canada. A high rate of LNG imports is needed to balance the market, despite slow demand growth of 0.7 percent per year. The Reference Case assumes that high natural gas prices in the United States and the availability of import infrastructure will attract LNG to the U.S. market. However, LNG imports may be affected after 2015, as world natural gas prices rise, attracting LNG to other markets. It should be noted that this projection does not integrate U.S. requirements for LNG into a global market balance where LNG competes against indigenous gas to find the best economic opportunities.

The AEO 2006 includes several sensitivity cases built around: high or low oil price paths; high or low adoption of new technology favoring indigenous gas production and lowering gas prices; and high or low LNG supply based on the uncertainty of upstream developments in the LNG supply chain. Figure 2-57 shows the range of outcomes from these cases, which by 2030 range from more than double to only 30 percent of the Reference Case. The range between the various high and low cases is close to 23 billion cubic feet per day of natural gas delivered to the U.S. market, indicating the scope of very different outcomes according to the assumptions made.

LNG Trade and Infrastructure

Global natural gas supply patterns are shifting, as domestic production in major demand centers of North America and Western Europe fails to keep pace with growing demand. The growing LNG trade is expected to play a pivotal role in meeting this increasing demand. In North America, for example, LNG imports are expected to grow to around 20 percent or more of gas supply by 2030, compared to about 2 to 2.5 percent in recent years. The natural gas resource and reserve base in current and potential LNG exporting countries appears more than adequate to support a high growth rate. However, such growth will require a much stronger LNG supply and delivery infrastructure than currently available.



Source: Energy Information Administration (EIA), *Annual Energy Outlook 2006.*

FIGURE 2-57. *Projected U.S. LNG Imports — Alternative Cases*

LNG terminal and distribution infrastructure in the key markets of North America, Western Europe, East Asia, and South Asia is being developed at a scale that will support the expected increase in LNG imports. Uncertainty and risk are now more concentrated in upstream export projects. Less than expected or slower development of export projects could lead to tighter global supply, higher prices, and potential shortages, perhaps for extended periods.

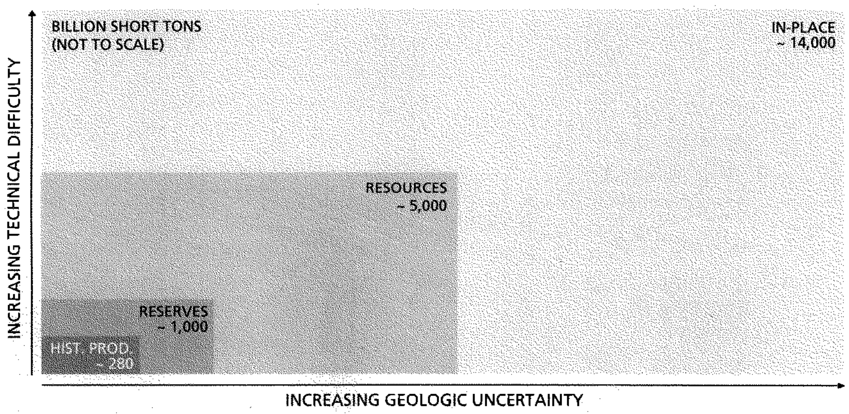
Coal

Key Observations—Coal

- *The global coal endowment is large (Figure 2-58) but national and local issues such as infrastructure limitations, environmental regulation, energy security, and coal conversion activities will determine how extensively coal is used in future global, regional, and national energy markets.*
- *Most business-as-usual energy forecasts expect an increasing demand for coal.*
- *Coal is the major feedstock for power generation growth. Future regulation of carbon dioxide emissions or carbon capture and sequestration will affect the direction of growth.*
- *China, India, and the United States have significant indigenous resources and are the largest coal consumers during the study time frame.*
- *International and U.S. coal transportation infrastructure will need additional capacity in order to meet projected demand.*

Global Coal Endowment & Resources

There are few independent estimates of the global coal endowment and resources. Almost all forecasts evaluated in this study use a World Energy Council assessment of the global coal resource base. World Energy Council assessments are based on self-reported, individual-country submissions that vary widely in quality. U.S. information on coal reserves and resources is extensive but outdated, since it is based on a Bureau of Mines 1974 study that used pre-1971 geological assessments and technology assumptions.[8]



Sources: (1) 1800 to 1980: Bernardo F. Grossling, "World Coal Resources," Financial Times Businesss Information, London, 1981; 1981 to 2005: Energy Information Administration, *International Energy Annual*. (2) World Energy Council, "Survey of Energy Resources," 2004. (3) Rogner, H-H., "Annual Review – Energy Environment," Institute for Integrated Energy Systems, 1997.

FIGURE 2-58. *Global Coal Endowment*

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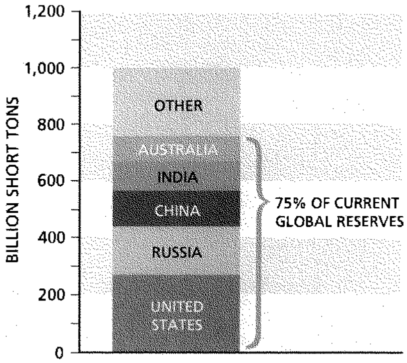
[8] U.S. Bureau of Mines, Compiled by U.S. Geological Survey, "Coal Resources of the United States," 1974.

About 280 billion short tons of coal have been produced globally to date, a small portion of the total coal resource base of approximately 5,000 billion short tons.[9] While coal resource estimates clearly suggest many years of supply, resources are not equally distributed among consuming centers, which may create significant trade and regional supply issues.

Global proved coal reserves are approximately 1,000 billion short tons.[10] This figure suggests a reserves-to-production ratio of about 150 years, making coal much more abundant in these terms than oil or gas. Given potential risks and constraints on other fossil fuel resources, countries with substantial indigenous coal resources such as China, India, and the United States, can see benefits to increasing coal use in their domestic energy mix (Figure 2-59).

Table 2-7 shows the five countries that hold over 75 percent of global proved coal reserves. The United States holds 27 percent of these reserves, the Russian Federation 17 percent, China 12.6 percent, India 10.2 percent, and Australia 8.7 percent.

Coal varies by chemical and physical properties that reflect its maturity from peat to anthracite. These properties are described by referring to the coal's rank. Low rank coals such as lignite and subbituminous have high moisture levels and low carbon content, resulting in low energy content. Higher rank coals such as bituminous and anthracite are characterized by less moisture and higher carbon and energy content. Lignite is at the bottom and anthracite is at the top of the coal rank scale. The quality of indigenous coal supplies varies between countries (Figure 2-60). This variation will affect end uses and environmental impacts. Global reserves are about evenly split between anthracite/bituminous coal and lignite/subbituminous coal.



Note: Global coal reserves are approximately 1.0 trillion short tons. Reserves data are available from limited sources and are generally self-reported by individual countries. Quality and vintage of estimates will vary.

Source: World Energy Council, 2004 Survey of Energy Resources.

FIGURE 2-59. *Estimated Global Coal Reserves*

U.S. Coal Resource Base

Coal is the most abundant fossil energy source in the United States. Figures 2-61 and 2-62 show regional

	United States	Russia	China	India	Australia
Estimated Coal in Place	3,968	6,600	5,572		
Identified Resources	1,731			279	479
Proved Amount in Place	493	220	1,110	152	118
Proved Recoverable Reserves	271	173	126	106	87

Sources: EIA, *Annual Energy Review 2006*; IEA, "Russia Energy Survey," 2002; Cui Mingxuan (ed.), "China Energy Development Report 2006," 2006; India, Ministry of Coal, 2006; Geoscience Australia, "Australia's Identified Mineral Resources," 2007.

TABLE 2-7. *Major Coal Resource Owners (Billion Short Tons)*

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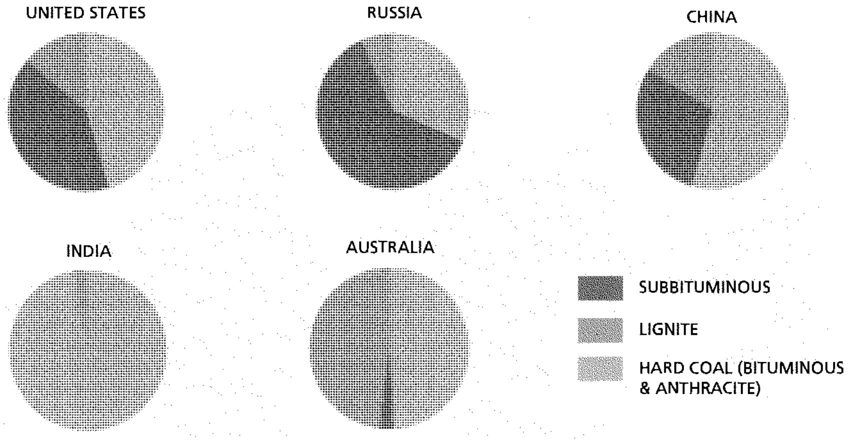
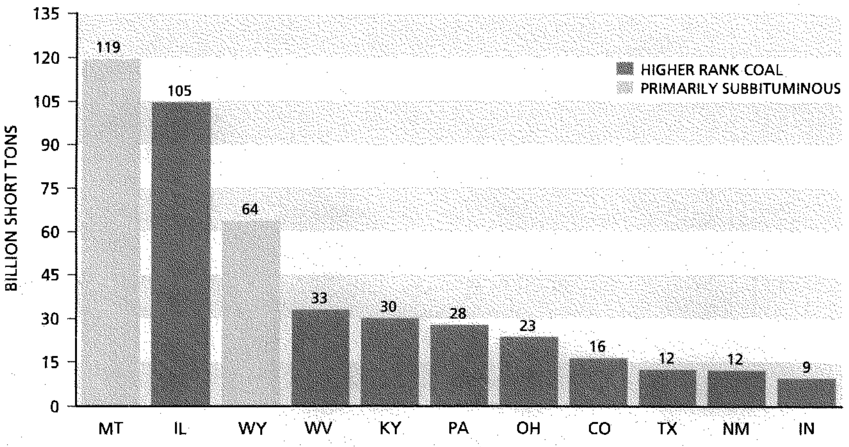
[9] Grossling, B.F., "World Coal Resources", 2nd Edition, Financial Times Business Information, London, England, 1981; and Rogner, H-H., "Annual Review – Energy Environment," Institute for Integrated Energy Systems, University of Victoria, 1997.

[10] World Energy Council, "2004 Survey of Energy Resources."



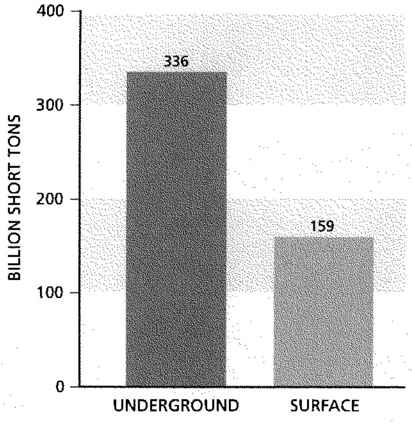
Source: World Energy Council, 2004 Survey of Energy Resources.

FIGURE 2-60. *Coal Rank Distribution in Large Resource Countries*



Source: Energy Information Administration, *Annual Energy Review 2005.*

FIGURE 2-61. *U.S. Coal Demonstrated Reserve Base by Key State*



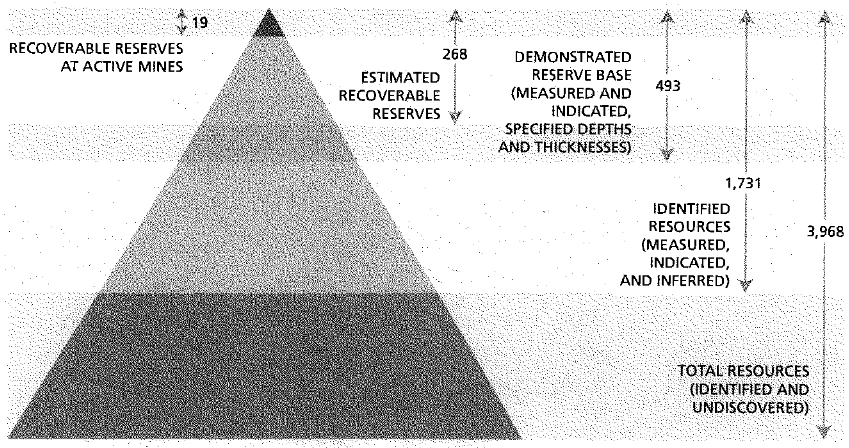
Source: Energy Information Administration, *Annual Energy Review 2005.*

FIGURE 2-62. *U.S. Coal Demonstrated Reserve Base by Mining Method*

distribution, rank, and extraction methods for U.S. coal resources. The EIA Annual Energy Review 2005 indicates that demonstrated U.S. coal reserves, equivalent to proved amount in place, amount to 493 billion short tons. Figure 2-63 shows the U.S. coal resource pyramid, which identifies known and estimated coal resources.

The EIA reports three mining regions: Appalachian, Interior, and Western. The Western region contains 47 percent of the reserve base, followed by Interior with 32 percent, and Appalachian with 21 percent. Of the 234.5 billion tons of Western reserves, about 77 percent are subbituminous coal; 13 percent are lignite; the remaining 10 percent are bituminous coal. The Western region contains all U.S. subbituminous reserves and 68 percent of U.S. lignite reserves, primarily in Montana and North Dakota. The bituminous coal is dispersed through the western states, with the largest reserves, in descending order, in Colorado, Utah, Wyoming, and New Mexico.

Approximately 92 percent of the Interior region's 158 billion short tons of reserves are bituminous coal, while the remainder is lignite. About 40 percent of the bituminous reserves are located in Illinois. The lignite reserves are located primarily in Texas, Louisiana,


19
RECOVERABLE RESERVES AT ACTIVE MINES
268
ESTIMATED RECOVERABLE RESERVES
DEMONSTRATED RESERVE BASE (MEASURED AND INDICATED, SPECIFIED DEPTHS AND THICKNESSES)
493
1,731
IDENTIFIED RESOURCES (MEASURED, INDICATED, AND INFERRED)
3,968
TOTAL RESOURCES (IDENTIFIED AND UNDISCOVERED)

Sources: Energy Information Administration 2004; and United States Geological Survey 1974.

FIGURE 2-63. *U.S. Coal Resources and Reserves Pyramid (Billion Short Tons)*

and Mississippi. In the Appalachian region, 92 percent of the reserves are bituminous coal and 7 percent are anthracite. Nearly all the anthracite is located in Pennsylvania.

Coal is critical to future energy security in the United States. The foundation for coal resource estimates is more than 30 years old and should be updated to account for new technologies, better subsurface information, and improved understanding of recovery efficiencies. The U.S. National Academies has found that current U.S. reserve estimates may be overstated and recommends that USGS undertake a new assessment of domestic coal reserves and resources.[11]

Total U.S. Coal Production and Disposition

The United States is self-sufficient in coal production, virtually matching estimated consumption through the study time frame. EIA forecasts total U.S. coal production to increase an average of 1.6 percent per year from 2005 through 2030, in order to meet increasing domestic demand. The primary consumer of coal in the United States is the power industry, using 92 percent of the 1.128 billion short tons burned in 2005. The EIA AEO 2007 forecasts that power generation will decrease to 89 percent of coal consumption by 2030, although total volume is increasing significantly (Figures 2-64 and 2-65). If implemented at scale, new energy applications, such as CTL and coal-to-gas (CTG) would consume an increasing share of coal production later in the study time frame, although this is likely to remain small relative to total consumption.

Most forecasts received by the study project relatively low CTL production volumes in the United States (Figure 2-66). Forecasting organizations such as the EIA may make widely varying estimates of U.S. coal consumption for CTL and CTG conversion, depending on the date of their forecast. Between the 2006 and 2007 Annual Energy Outlooks, the EIA decreased its forecast for CTL and CTG coal consumption from 190 million to 112 million short tons per year in 2030 (Figure 2-67). The variation in forecasts is even more dramatic between organizations. The Southern

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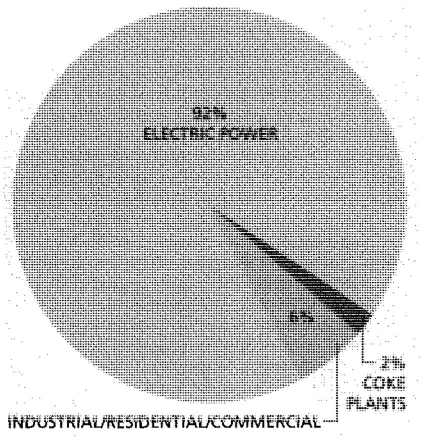
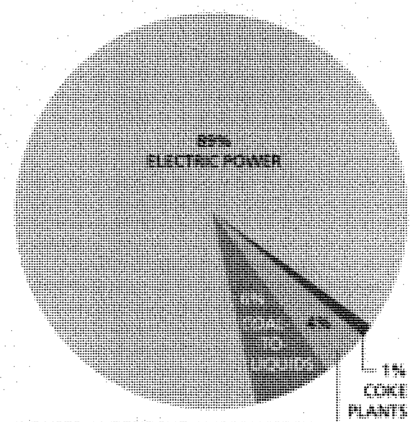
[11] U.S. National Academies – Board on Earth Sciences and Resources (BESR), "Coal: Research and Development to Support National Energy Policy," 2007.



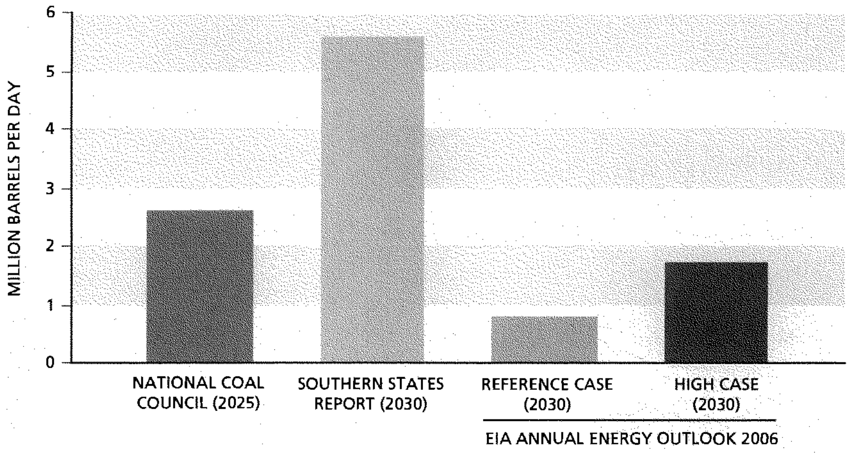
Source: Energy Information Administration, *Annual Energy Outlook 2007.*

FIGURE 2-64. *U.S. Coal Consumption by Sector in 2005 (1.128 billion short tons)*



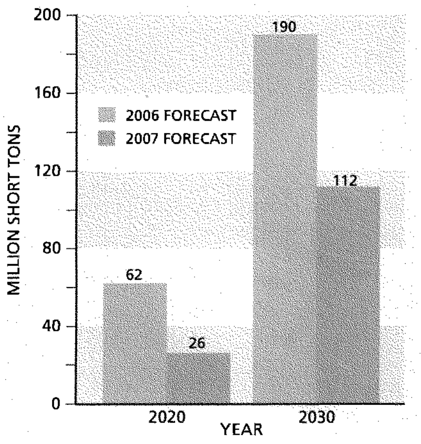
Source: Energy Information Administration, *Annual Energy Outlook 2007.*

FIGURE 2-65. *U.S. Coal Consumption by Sector in 2030 (1.772 billion short tons)*



Source: NPC Survey of Outlooks.

FIGURE 2-66. *Projected U.S. Coal-to-Liquids Production*



Source: Energy Information Administration, *Annual Energy Outlook 2006* and *2007*.

FIGURE 2-67. *One-Year Change in EIA Reference Case Forecast of U.S. Coal-to-Liquids Coal Consumption*

States Energy Board and the National Coal Council also produced forecasts for converting coal to liquids and to gas in order to increase U.S. energy security and displace oil imports (Figure 2-68).[12] The Southern States Self-Sufficiency case projects U.S. CTL production reaching at least 20 percent of U.S. oil demand in 2030. This projection is an order of magnitude greater than the most recent EIA forecast.

Globally, China's relatively low-cost coal may allow economical production of CTL. In the IEA WEO 2006 Reference Case, CTL production will be less than 1 MB/D by 2030, primarily in China. Elsewhere, higher coal costs, capital costs, and significant CO_2 emission concerns are likely to constrain CTL production between now and 2030. The EIA IEO 2007 Reference Case projects global CTL production of 2.4 MB/D in 2030, while production reaches 3.9 MB/D in the High Price Case, or about 4 percent of global oil demand. For a full discussion of CTL technology, see the Coal-to-Liquids Topic Paper included on the CD distributed with the study.

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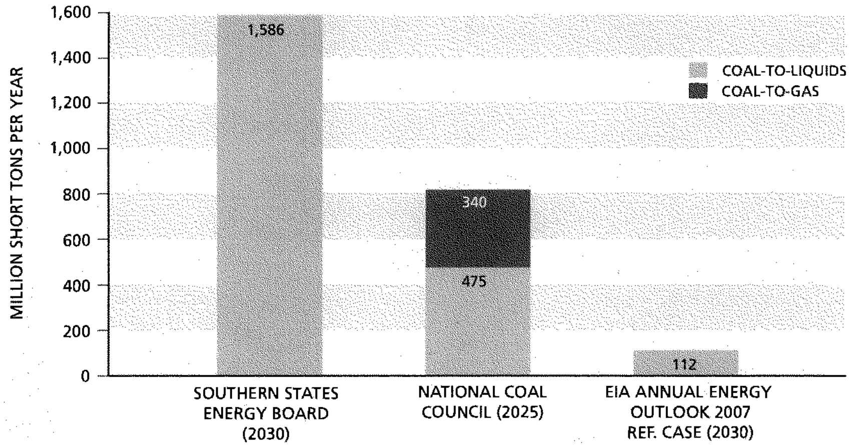
[12] Southern States Energy Board, "The American Energy Security Study," 2006; and The National Coal Council, "Coal: America's Energy Future," 2006.



Source: NPC Survey of Outlooks.

FIGURE 2-68. *Projected U.S. Coal-to-Liquids and Coal-to-Gas Coal Consumption*

Infrastructure

The extent to which coal contributes to U.S. energy requirements will depend heavily on the capacity of coal transportation infrastructure. Railroads, barges, and trucks are all critical modes of transport for coal. Each mode faces challenges, some of which are unique to it and others that are common to all modes. For each mode, having adequate capacity to meet growing demand is perhaps the most pressing need. Roads and waterways depend on publicly owned and maintained infrastructure. Waterway infrastructure is generally in need of significant maintenance and improvement. Railroads, on the other hand, rely overwhelmingly on privately owned, maintained, and operated infrastructure. They will need a balanced regulatory and legislative environment to ensure sufficient private capital is invested to provide the additional capacity required by energy forecasts.

Global Coal Production and Disposition

Global coal production is projected to increase substantially, primarily to meet demand for electricity and, to a smaller extent, for CTL and CTG conversion. Most Reference Cases project a 50 to 60 percent increase in coal production between 2005 and 2030. Global production is currently 6.5 billion short tons per year and is forecast to increase to between 9.5 and 11.0 billion short tons by 2030. Figure 2-69 shows Reference Case supply forecasts for EIA, IEA, the European Commission, and the U.S. Climate Change Science Program (CCSP).[13] The Reference Cases are generally based on business-as-usual assumptions for economic and population growth, without significant environmental constraints. IEA forecasts that global coal demand will increase by an average annual rate of 1.7 percent per year from 2004 to 2030. EIA projects 2.0 percent annual growth.

Much of the world's coal is consumed in the country where it is produced. In 2004, 68 percent of global primary coal consumption was used to generate electric power and heat. Industry used 18 percent. This pattern of consumption is expected to remain quite stable over the study timeframe, although the higher efficiency of new generating plants will mitigate consumption growth. In 2030, coal for power and heat generation is projected at 73 percent of total primary coal consumption, while

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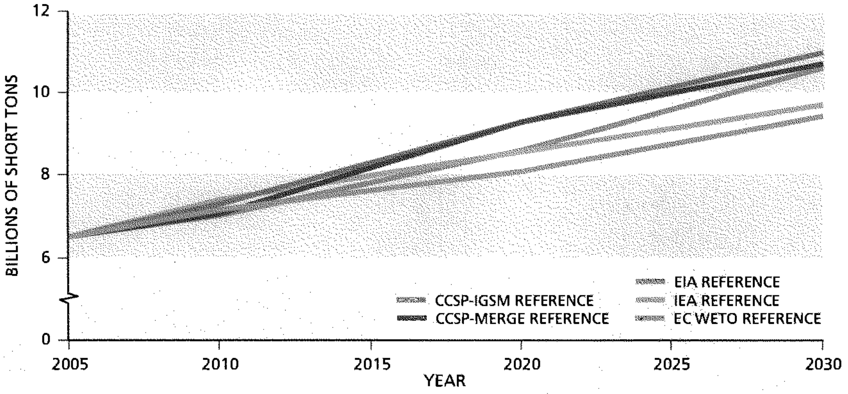
[13] European Commission, "World Energy Technology Outlook – WETO H2," 2006; and Climate Change Science Program, "CCSP Synthesis and Assessment Product 2.1, Part A: Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations," 2006.



Note: All Forecasts Normalized to 6.5 Billion Short Tons In 2005.
Sources: Climate Change Science Program (CCSP); Energy Information Administration (EIA), *International Energy Outlook 2006*; International Energy Agency (IEA), *World Energy Outlook 2006*; and European Commission, *World Energy Technology Outlook 2050* (EC WETO), 2006.

FIGURE 2-69. *Global Coal Production Reference Cases*

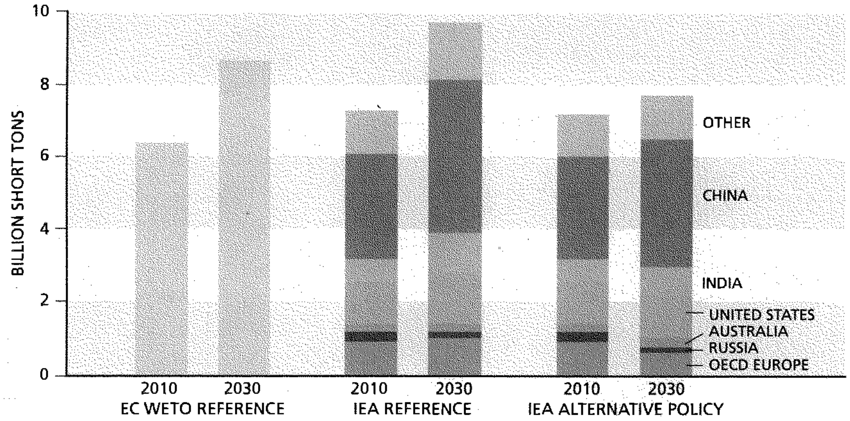
industry remains at 18 percent. Electricity generation remains the primary driver of coal consumption. IEA projects the share of coal in global power generation as increasing from 40 percent in 2004 to 44 percent in 2030.

Most growth in coal production will occur in rapidly expanding economies. Coal consumption in developing Asia is projected to rise from 2.9 billion short tons in 2004 to 4.5 billion short tons in 2015 and 6.1 billion short tons in 2030, a growth rate over the period of 2.7 percent per year. China and India heavily dominate coal consumption in the region (Figure 2-70) accounting for nearly 80 percent of annual incremental demand through 2030. They also account for 71 percent of the projected 6 billion kilowatt-hour increase in coal-based electricity generation.

Coal consumption in OECD Europe is projected to grow only slightly in Reference Cases, increasing from 761 million short tons to 778 million short tons per year from 2005 to 2030. In this case, gains in power generation are offset by losses in industry. The coal share of power generation is projected to decrease from 29 percent to 27 percent to the benefit of natural gas. Coal inputs to power generation are projected to fall in the period to 2020 and then increase between 2020 and 2030 as nuclear power plants are retired and the assumed competitiveness of coal improves relative to natural gas. OECD-Europe coal production is projected to decline from 467 million short tons in 2005 to 324 million short tons in 2030. Given that consumption is projected to rise, this suggests an increase in net imports from 293 million short tons to 454 million short tons over the period.

Coal consumption in Russia and other countries of the former Soviet Union is projected to rise by an annual average of 1.1 percent between 2004 and 2015, then decline to the 2004 level by 2030. Industrial use of coal is projected to increase throughout the period while coal consumption in power generation is projected to fall. Coal-fired power generation capacity is forecast to decline throughout the period as natural gas replaces aging coal-fired plants. Coal's share of power generation is projected to fall significantly from 21 percent in 2015 to 15 percent in 2030. Latin America, the Middle East, and Africa are expected to be relatively minor consumers of coal.

Demand increases for coal vary geographically, and the remaining resource estimates vary widely for the five largest resource owners. While India has sufficient



Sources: European Commission, *World Energy Technology Outlook 2050* (EC WETO), 2006; and International Energy Agency (IEA), *World Energy Outlook 2006*.

FIGURE 2-70. *Projected Regional Coal Consumption (2010 vs. 2030)*

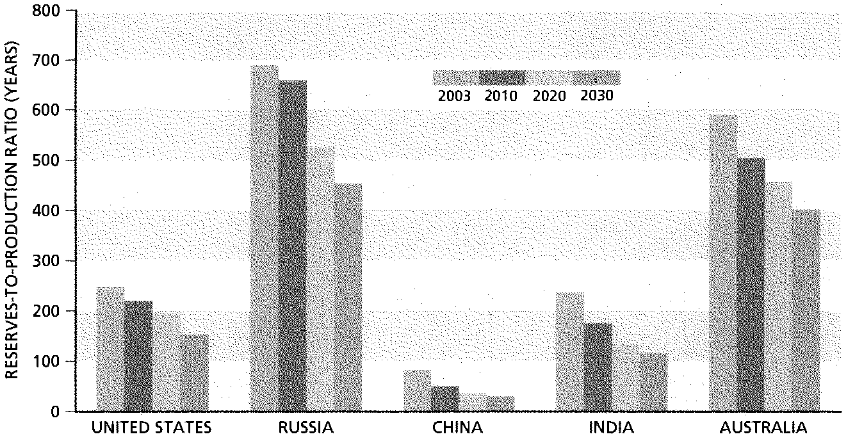
coal reserves for more than 200 years of consumption at 2005 levels, China has coal reserves for only 52 years (Figure 2-71) at 2005 levels. China's planned coal production capacity in 2010 is 2.1 billion short tons. Restructuring of township coal mines is expected reduce production capacity to 1.65 billion short tons in 2020. When compared to many consumption forecasts, the reduction suggests that China may rely increasingly on coal imports or may need to develop new domestic reserves. With Chinese industrial demand growing significantly, especially for steel making, China will require not only coal in quantity, but the right type of coal. Restructuring plans should be viewed in this light.

China and India will be the fastest growing markets for coal exporters. Regions well situated to serve those markets are likely to experience the greatest growth. Russia has a large coal resource base and could supply foreign markets such as China. Australia is projected to increase exports from 257 million short tons in 2005 to 435 million short tons in 2025. Indonesia is expected to increase exports from 138 million short tons to 203 million short tons. This suggests that Australia and Indonesia will represent 70 percent of the increase in coal exports between 2005 and 2025, rising from 46 percent of global coal exports in 2005 to 53 percent in 2025.

Infrastructure is unlikely to present a long-run constraint on Australian coal exports, although Indonesia may prove to be more problematic. Although Indonesian coal resources are substantial, a significant proportion is located some distance from the coast and dedicated port terminals. Currently, a substantial portion of Indonesia's coal exports is transported by barge and later transshipped. Investment needed to provide the infrastructure for interior coal deposits is also likely to be significant.

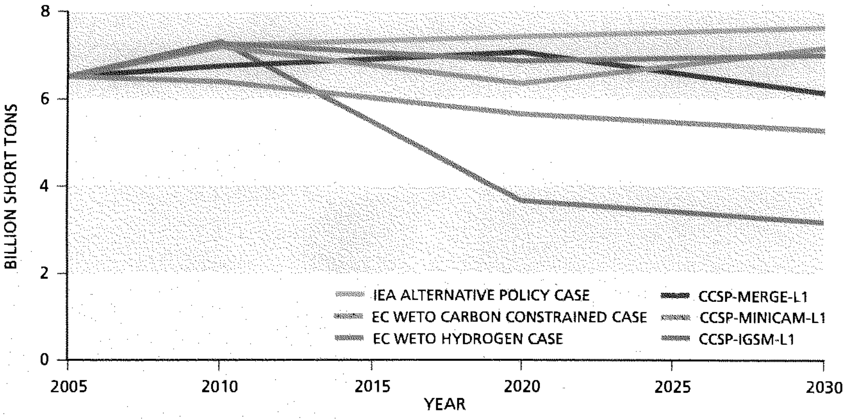
Carbon Constraints

Carbon-constrained cases generally show flat-to-declining global coal production as energy demand is met by fuels with lower carbon content, including renewable sources (Figure 2-72). Total coal production continues to increase in the IEA Alternative Policy Case, but is approximately 20 percent less than coal production in the IEA Reference Case. Most of the reduction in coal demand results from fuel switching and energy savings in the power sector. The European Commission's *World Energy Technology Outlook 2050* (WETO) carbon-constrained case represents ambitious policies for long-term stabilization of atmospheric carbon



Sources: World Energy Council 2006; and Energy Information Administration, *International Energy Outlook 2006.*

FIGURE 2-71. *Reserves-to-Production Ratios in Major Coal-Producing Countries*



Note: All forecasts normalized to 6.5 billion short tons in 2005.
Sources: International Energy Agency (IEA), *World Energy Outlook 2006;* European Commission, *World Energy Technology Outlook 2050,* (EC WETO) 2006; and Climate Change Science Program (CCSP).

FIGURE 2-72. *Projected Carbon-Constrained Coal Production*

dioxide concentrations at 500 parts per million by volume (ppmv) by 2050.

Technology development is critical in shaping a future carbon-constrained energy system. WETO envisages incremental improvements in large-scale power generation and renewable technologies. The WETO-H2 scenario incorporates new technology to decrease total energy consumption and increase the use of hydrogen, which may be produced from lower carbon energy sources. The CCSP cases designated L-1 are based on stabilizing atmospheric carbon dioxide at 450 ppmv by 2100. Three integrated assessment models from MIT (IGSM), Stanford (Merge), and Joint Global Climate Change Research Institute (MiniCam) forecast climate change based on input assumptions, with each addressing the carbon issue for different energy inputs.

In a carbon-constrained world, CCS is one of the technology and policy prerequisites for maintaining coal's significant role in the energy system. For a full discussion of carbon management and carbon capture and sequestration, see the Carbon Capture and Sequestration Topic Paper included on the CD distributed with this report.

Coal Supply Challenges

Many challenges faced by the coal industry (Table 2-8) are common to other carbon-based fuels. The requirement for affordable energy must be balanced with environmental and other policy issues, while maintaining infrastructure to transport resources from supply to demand regions. Permitting new facilities takes longer, costs more, and is subject to more scrutiny than in the past. Construction, labor, equipment, and supply costs have escalated significantly in recent years and are more volatile than in the past, contributing to higher, less predictable production costs. Carbon management is likely to become a factor in future coal use as carbon policies develop in the United States and globally. Land owners and various interest groups are vocal in their objections to new surface mines, often delaying the permitting process and increasing development costs. Local, state, and federal regulations that place land use restrictions on private lands, such as populated areas, also limit mining access. Table 2-8 summarizes the coal supply challenges that will apply in different combinations and places over the study time frame.

Biomass

Key Observations—Biomass

- *Energy from Biomass can be converted to electricity, heat, and biofuels; forecasts show considerable growth potential while meeting the world's need for food.*
- *The cellulosic biomass resource is substantial, but technology does not currently exist to convert it to large volumes of liquid fuels at competitive economics.*

		Access	Investment	Infrastructure	People and Equipment	Environment
Large Producers	*Current Annual Production (Billion Short Tons)*					
China	~3		X	X		X
United States	~1	X	X	X	X	X
OECD Europe	~1					X
Production Growth	*2005-2030 Expected Growth (Billion Short Tons)*					
China	+1		X	X		X
India	~0.5		X	X		X

Note: An X in any column means that the matter is problematic or open to question.

Source: NPC Survey of Outlooks.

TABLE 2-8. *Coal Production Challenges*

- *In a carbon-constrained environment, biomass-fired power generation will be an attractive use of biomass.*
- *Biomass resources will continue to be converted to biofuels as a supplemental contributor to the U.S. transportation fuel mix, with public policy as a factor in overall market penetration.*

Biomass was the primary source of energy before the industrial age developed through intense use of coal, petroleum, and natural gas. Like coal and natural gas, biomass is a local energy source that could provide significant additional supply, although it constitutes only a small fraction of current primary energy supply. Like many unconventional and alternative energy sources, biomass presents new demands on other resources such as land and water. Since biomass is renewable, it is expected to have a lower carbon footprint than other widely available energy sources.

Biomass can be burned, gasified, fermented, or otherwise processed to provide energy as electricity, heat, and biofuels. However, the infrastructure developed for coal, petroleum, natural gas, and other energy sources may not have the capability to support biomass as the main source of primary energy. Where possible, biomass has been incorporated economically into the value chains that link energy sources to products and markets. For example, biomass has been co-fired with coal in power plants; ethanol produced from corn or sugarcane has been blended with gasoline; biodiesel has been produced from palm and soy. In each case, incorporating biomass in the corresponding value energy chains required only minor modifications to existing infrastructure.

The biomass energy value chain has many characteristics similar to those of oil, coal, and natural gas. However, since the underlying source is solar energy, biomass is characterized by low energy density and production over large areas. Land use, transportation logistics, harvesting, storage, and processing of biomass feedstocks and products are key hurdles to widespread production. The sources of energy used to convert biomass to products and the energy balance of the conversion processes are also significant considerations for biomass use. For example, coal is an important source of heat for some biorefineries in the United States. Significantly reducing the carbon footprint and improving the energy balance of these refineries would require developing and using processes that incorporate more biomass energy.

Biomass Forecasts

Most business-as-usual forecasts show continued growth of the energy supplied from biomass.[14] Great care must be taken when analyzing these forecasts, however, because they sometimes distinguish between commercial biomass and existing biomass use and incorporate energy conversion efficiencies of biomass into final fuels such as ethanol, and thus do not refer to real primary energy. The EIA Reference Case, for example, shows biomass growing at small rates. By comparison, the IEA Reference Case projects biomass use in 2030 at more than four times higher than 2005. Business-as-usual cases typically forecast biomass penetration as biofuels for transportation. These forecasts project up to 5 MB/D of biofuels in the year 2030, representing almost 5 percent of total liquids supplied. This projected volume is still a small fraction of the total energy mix.

Forecasts that are not business as usual project dramatic increases in biomass as an energy source based on policy objectives. Stabilizing atmospheric carbon dioxide, increasing the efficiency of energy consumption, or reducing carbon impact are typical policy objectives assumed in these forecasts. For example, a scenario that accelerates stabilization of carbon dioxide concentrations includes policies that impose carbon-neutral primary energy production in the coming decades. The policies result in rapidly increasing biomass use; rapid growth of new nuclear-based electricity generation; and widespread use of CCS for all fossil fuel based power plants. This case reduces total global liquids demand to 98 MB/D by 2030, of which biofuels supply more than 23 MB/D, or almost 25 percent.[15]

As with all resources, biomass needs to be produced, converted, and delivered in a useful form for consumers. Current processing technologies for corn and sugarcane seek to balance biomass use for food, feed, and fuel production. This delicate balance is subject to intense study. Many technology developments target the balanced and adequately supplied food, feed, and fuel markets. The use of co-products of ethanol processing, such as distiller's dry grains used in livestock feed, contribute to the balance by allowing the same corn crop to serve as a source of both fuel and feed.

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[14] Business-as-usual forecasts do not incorporate policies, taxes, or incentives that are not currently in force or would preclude direct economic competition between sources of energy within the established framework.

[15] U.S. CCSP Level 1 Stabilization Scenario, IGSM Model. This scenario imposes a very high penalty on carbon-related emissions in order to achieve such an accelerated transition away from non-carbon neutral fuels. The model also constrains the growth in nuclear energy. The economic impacts of such carbon constraints can affect economic growth.

Studies that estimate the annual potential for biomass production are balanced by forecasted future global demand for food and feed. Any surplus, in the absence of cross-competition, could be available to supply energy. Forecasts usually consider such factors as available arable land, water resources, and changes in land use. Assuming widespread use of recent advances in biotechnology and modern land management techniques, the potential energy available from biomass is estimated to be approximately 952 quadrillion Btu, or on the order of annual human energy consumption. The efficiency of converting potential biomass energy into forms suitable for widespread consumption is a matter of considerable interest.

Biotechnology is expected to play a significant role in expanding global biomass production, with crop yields in the next few decades increasing at a faster rate than historically. For example, marker-assisted plant breeding can increase trait development by a ten-fold rate over conventional breeding. The ability to engineer specific new traits into crops may bring about remarkable changes in crop production and crop adaptability to different growing conditions. New technologies could potentially increase U.S. corn production to 25 billion bushels by 2030. Using conventional conversion methods, a crop of this size could potentially yield 54 billion gallons of ethanol by 2030, or 3.5 MB/D. This forecast contrasts with both the carbon-constrained case, which shows volumes above 20 MB/D and with the more conservative EIA IEO 2007 Reference Case, which forecasts about 1.5 MB/D.

Ethanol

Ethanol is an alcohol that can be used directly as an alternative fuel or blended with gasoline. It is made by fermenting sugars from many agricultural products and food wastes, including cellulose. The technology for producing ethanol from corn (90 percent of U.S. ethanol) and sugarcane (Brazil) is well established. Current technologies such as direct combustion and the production of ethanol or biodiesel have made wood, dung, cereals, sugar crops, and oilseeds the current leaders in bioenergy crops. Global production of ethanol has more than doubled over the last five years, to about 9 billion gallons in 2005 or 0.6 MB/D.

As mentioned above, conventional conversion methods in a business-as-usual case may produce up to 3.5 MB/D of ethanol in the United States by 2030. Large additional increases would require technology development to convert lignin and cellulose more efficiently into useful fuel. Technologies that use non-foodstuff biomass could potentially augment energy crop use for fuel production by increasing (1) overall process efficiency and (2) the biomass resource available for conversion.

Infrastructure

Several steps are necessary to increase the use of biomass as an energy source: bioenergy crops, preferably perennial, must be developed for excess agricultural land and marginally arable land; systems are required to harvest, collect, and store energy crops; efficient conversion and delivery systems must be developed. Widespread adoption of agricultural best practices could enable development of better food crops and better use of arable land now in production. Much of the infrastructure needed to increase biomass use does not exist today, limiting the growth rate of biomass, much as with any new energy source. Development of the sugarcane-based ethanol industry in Brazil is an example of how public policy can guide development of a biomass energy source.

Biomass Resource Potential

The growing use of certain biomass feedstocks as an energy source raises concerns about the availability of biomass for foodstuffs. The multiple uses of land compete and increase the value (and cost) of land. However, forecasts show that available land could produce enough biomass to provide food, feed, and fuel. The United Nations Food and Agriculture Organization (FAO) confirms this expectation in its recent estimate of population, food needs, and agricultural development from 2015 to 2030. According to the FAO, agricultural production of food and feed will continue to expand to meet global needs through 2030. Second-generation or cellulosic ethanol would reduce the potential for competition between food crops and energy crops by using plant waste and a specific energy crop such as switchgrass. However, second-generation biomass conversion technologies are currently in the research and early demonstration phases. The timing of their transition to commercial operation at scale remains uncertain.

Various studies over the past 20 years have assessed the potential of agriculture to produce both energy and food for the world. While conclusions from these studies differ, the annual resource potential could reach approximately 238 to 476 quadrillion Btu of biomass

Biomass Category	Main Assumptions and Remarks	Potential 2050 (EJ/yr) [1]	Potential as Cellulosic Ethanol (Quads) BOE [5]	Potential as Pyrolysis Bio Oil (Quads) BOE [6]	Potential as Methanol (Quads) BOE [7]	Potential as Methane via Anaerobic Digestion (Quads) [8]
Energy farming on current agricultural land	Potential land surplus: 0-4 Gha (more average: 1-2 Gha). On average higher yields are likely because of better soil quality: 8-12 dry t/ha/yr is assumed if intensive agricultural practices are used. [2]	0-700 [100-300]	0-305 Quads 0-52 billion BOE	0-464 Quads 0-80 billion BOE	0-398 Quads 0-68 billion BOE	0-199 Quads 0-34 billion BOE
Biomass production on marginal lands	On a global scale a maximum land surface of 1.7 Gha could be involved. Low productivity of 2-5 dry t/ha/yr. [2]	0-150 [60-150]	0-65 Quads 0-11 billion BOE	0-99 Quads 0-17 billion BOE	0-85 Quads 0-15 billion BOE	0-43 Quads 0-7 billion BOE
Bio-materials	Range of land required to meet the additional demand for bio-materials: 0.2-0.8 Gha. Average productivity: 5 dry t/ha/yr.	0-150 [40-150] [3]	0-65 Quads 0-11 billion BOE	0-99 Quads 0-17 billion BOE	0-85 Quads 0-15 billion BOE	0-43 Quads 0-7 billion BOE
Residues from agriculture	Estimates from various studies. Potential depends on yield/product ratios and the total agricultural land area and type of production system.	15-70	6.5-30 Quads 1.1-5.1 billion BOE	9.9-46 Quads 1.7-7.9 billion BOE	8.5-40 Quads 1.5-7 billion BOE	4.3-20 Quads 0.7-3.3 billion BOE
Forest residues	The (sustainable) energy potential of the world's forests is unclear. Part is natural forest (reserves). Range is based on literature data.	0-150 [30-150]	0-65 Quads 0-11 billion BOE	0-99 Quads 0-17 billion BOE	0-85 Quads 0-15 billion BOE	0-43 Quads 0-7 billion BOE
Dung and Organic waste	Use of dried dung. Low estimate based on global current use. High estimate: technical potential. Utilization (collection) in longer term is uncertain.	5-105 [4]	2.2-46 Quads 0.37-7.8 billion BOE	3.3-69 Quads 0.57-11.9 BOE	2.8-59 Quads 0.5-10.1 billion BOE	1.4-30 Quads .25-5.1 billion BOE
Total	Most pessimistic scenario: no land available for energy farming, only utilization of residues. Most optimistic scenario: intensive agriculture concentrated on the better quality soils.	40-1100 [250-500]	17.4-480 Quads 3 – 84 billion BOE	26.5-729 Quads 4.6-125 billion BOE	22.7-625 Quads 108 billion BOE	11.3-312 Quads 54 billion BOE

Notes

1 Bio-Energy supply, where two ranges are given, numbers between brackets give the range of average potential in a world aiming for large-scale utilization of biomass. A lower limit of zero implies that potential availability could be zero, e.g. if we fail to modernize agriculture so that more land is needed to feed the world.

2 Heating value: 19 GJ/t dry matter.

3 This value could even be negative: the potential biomass demand for producing bio-materials (such as bio-plastics or construction materials). These markets can represent a large demand for biomass that will reduce the availability of biomass for energy. However, the more bio-materials are used, the more organic waste (eventually) will become available for energy. Such use of biomass results in a "double" GHG benefit as well through avoided emissions in manufacturing materials with fossil fuels and by producing energy from the waste. Thus, calculating the potential biomass availability for energy is not straightforward adding the figures of the different rows. More details are given in [Hoogwijk et al., 2003].

4 The energy supply of bio-materials ending up as waste can vary between 20 and 55 EJ (or 1100-2900 Mt dry matter) per year. This range excludes cascading and does not take into account the time delay between production of the material and "release" as (organic) waste.

5 Future cellulosic ethanol yield - 46% on an energy basis (C. Hamelinck/ Dissertation, Outlook for Advanced Biofuels/Utrecht: Universiteit Utrecht, Faculteit Scheikunde, Proefschrift Universiteit Utrecht. Met literatuuropgave en samenvatting in het Nederlands. ISBN: 90-393-3691-1)

6 Future pyrolysis oil yield 70% on an energy basis (A.P.C. Faaij / Energy Policy 34 (2006) 322–342).

7 Future methanol yield 60% via syngas on an energy basis (C. Hamelinck/ Dissertation, Outlook for Advanced Biofuels/Utrecht: Universiteit Utrecht, Faculteit Scheikunde, Proefschrift Universiteit Utrecht. Met literatuuropgave en samenvatting in het Nederlands. ISBN: 90-393-3691-1).

8 Future anaerobic digestion yield of 30% on an energy basis (T. Bridgwater J Sci Food Agric 86:1755–1768 (2006).

Source: Faaij APC, et al: *Energy for Sustainable Development*, Volume X, number 1 (March 2006).

TABLE 2-9. *Biomass Categories and Energy Potentials*

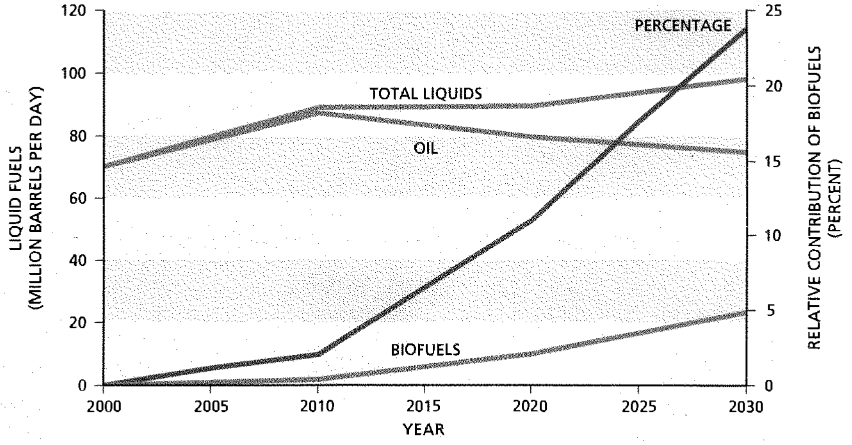
energy, produced while still feeding a growing global population (Table 2-9). The higher estimate is equivalent to about 68 percent of projected global energy needs in 2030. However, various factors will influence the potential penetration of biomass as an energy source, the most important being the availability of conversion technology and infrastructure, and competing delivered energy costs. Business-as-usual forecasts project biomass as supplying approximately 10 percent of global energy needs by 2030. Forecasts that incorporate strong carbon-management policies see biomass energy growing considerably, to 15 percent of total global energy demand by 2030 and 30 percent by 2100.[16] Specifically, with targeted policies and restraints on carbon dioxide emission, the U.S. CCSP Level 1 Stabilization Scenario, IGSM Model, forecasts that bio-fuels will reach nearly 25 percent of liquid fuels on a volumetric basis in 2030 (Figure 2-73).

In summary, production of biofuels and energy from the large potential biomass resource is projected to grow over the study time frame. Policies to stabilize carbon dioxide concentrations are forecast to strongly stimulate growth in biomass use, though possibly with significant economic impact. There will be tradeoffs between different lower carbon alternatives depending on the type of carbon constraint. Ethanol from biomass is commercially produced today and is part of the energy supply. In order to reach its potential market penetration, energy from biomass requires considerable investment and supportive public policies. These requirements apply particularly to associated infrastructure and the development and demonstration of new fuel conversion technologies for biomass not intended for food or feed. For a full discussion of Biomass as a potential energy source, see the Biomass Topic Paper on the CD included with this report.

Non-Bio Alternative Energy Sources

Key Observations—Non-Bio Alternatives

- *Forecasts for the possible role of nuclear energy vary from limited growth to cases where nuclear power is employed for power generation as a replacement for fossil fuels with a higher carbon footprint.*
- *The diversity of views about nuclear energy's future reflects conflicting positions and perceptions about*



Source: U.S. Climate Change Science Program, Level 1 Stabilization Scenario, IGSM Model.

***FIGURE 2-73.** Accelerated Global Biofuels Production under Considerable Carbon Dioxide Emission Constraints*

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[16] Energy demand in these highly carbon constrained scenarios is only marginally greater in 2100 than it is today. The carbon constraint greatly impacts economic activity.

safety, waste, nuclear proliferation, and the nuclear fuel cycle.

- *Some alternative sources of energy, much like unconventional fossil fuels, have secondary resource impacts (water, land, fuel, etc.) that are not completely understood and may be significant as they reach new scales of supply.*

This section summarizes discussions of alternative energy sources in the Renewables and the Hydrogen Topic Papers on tbe CD distributed with this report.

Hydropower and Ocean

Historically, hydroelectricity has dominated non-biomass alternative energy sources. Dams have been developed globally to provide vast supplies of electricity at very low marginal production costs. Industrialized nations have already developed most of their hydroelectric resources. Additional, limited opportunities to increase hydroelectric production may exist in industrializing and economically developing nations, subject to growing questions about their environmental and social impact. Ocean and small-scale hydroelectric technologies currently being developed and deployed may also provide additional distributed and localized power with reduced environmental footprint.

Wind

Energy from wind has grown significantly in recent decades and is forecast to grow several times faster than overall energy demand, thus increasing its share of the supply mix. Given infrastructure requirements and a current share of less than 2 percent of energy supply, it will be some time before wind supplies a significant portion of global energy requirements. One of the main challenges faced by wind and other intermittent sources of energy is the need to maintain ready reserve power capacity. Incentives and tax credits have made wind power an attractive option in many markets. Additional technology development could eliminate the need for incentives.

Solar

Concentrated solar power (CSP) technology is being deployed globally. CSP costs are not yet competitive with large-scale electricity production from fossil fuels, but may be attractive for smaller and remote applications. Research in new materials for photovoltaic electricity generation (PV) continues to reduce its costs. PV technology has niche applications, but does not make significant global contributions to energy supply.

Geothermal

Conventional geothermal is competitive as a base-load power source in areas with readily accessible, naturally occurring, and plentiful underground steam. As with large-scale hydroelectric dams, conventional geothermal energy presents limited opportunities for new supplies. However, enhanced geothermal systems (EGS) that harvest heat by introducing water into an underground heat source to produce steam may have future potential growth. EGS technology significantly leverages existing oil and natural gas related technologies.

Nuclear

Despite its considerable growth in previous decades, nuclear power represents only 5 to 6 percent of the total global energy supply mix and less than 20 percent of global electricity generation. Regions and countries, however, can vary significantly from the global average. Countries such as France that have made progress in developing nuclear power tend to show contributions that are much larger than average.

Views about nuclear energy's future role are diverse. Most forecasts that stipulate business as usual show only limited changes in the contribution of nuclear energy to the energy supply mix. These forecasts refer to difficulties in siting, financing, and operating nuclear facilities, as well as in disposing of nuclear waste given environmental and non-proliferation concerns in industrialized nations.

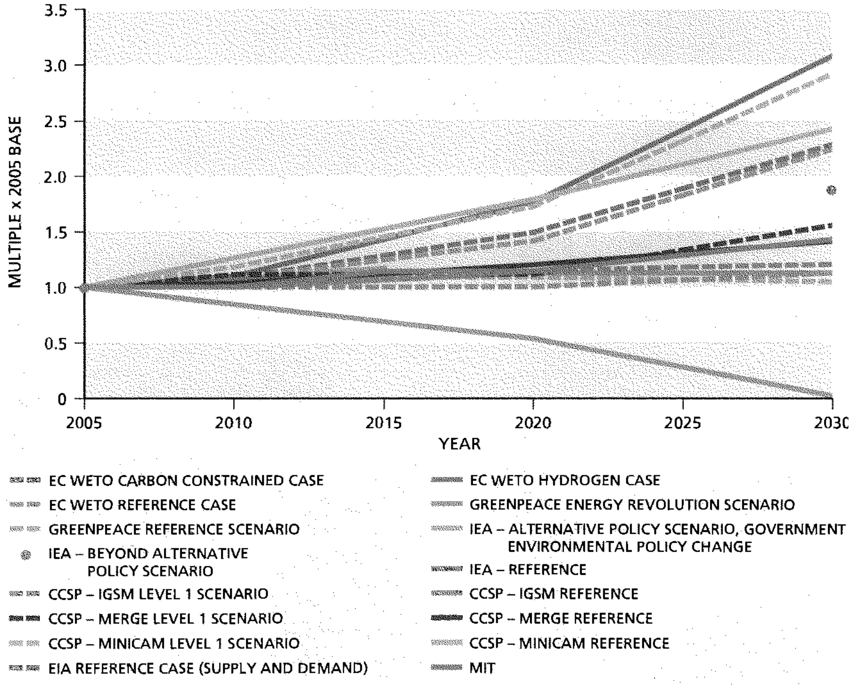
Nuclear power is forecast to grow in industrializing nations, particularly China, which have the greatest need for new sources of abundant energy. The forecasts reviewed in this study usually do not include constraints in the uranium fuel value chain, but do incorporate concerns about the fuel cycle and proliferation. Moreover, recent developments of futures contracts for uranium allow for risk mitigation. These forecasts show an increasing role for nuclear power in the latter part of the century, parallel with growth in coal-fired power plants.

As with biomass, nuclear energy becomes an important energy source in forecasts that include policy objectives to stabilize atmospheric carbon dioxide, promote efficient energy use, or reduce its carbon impact. The resulting forecasted growth is a function of the policies implemented and the technologies available. For example, if carbon capture and sequestration is delayed or never widely deployed for coal-fired power plants, nuclear power may grow considerably, perhaps to 25 percent of total global energy demand by 2100. On the other hand, if carbon capture and sequestration is successful and widespread, the projected growth of nuclear power remains significant but more moderate.

The greatest projected growth of nuclear power generation by 2030 results in an increase of more than 200 percent from current levels (Figure 2-74). By comparison, forecasts that show a significant decrease in the share of nuclear energy show a marked increase in fossil fuel use. Or, they assume revolutionary gains in efficient energy use, resulting in only marginal demand growth.

Hydrogen

Hydrogen is being considered as a future energy carrier/fuel, given that its combustion emits only water. However, hydrogen's low molecular weight and energy density, as well as its production, handling, and storage, are very important hurdles to its widespread use. Hydrogen is an intermediate product, manufactured from a primary energy source and then used to move



Source: NPC Survey of Outlooks.

FIGURE 2-74. *Projected Nuclear Power Generation Relative to 2005*

energy from the source to a demand center. Currently, natural gas reforming is the main source of hydrogen. Integrated gasification combined cycle (IGCC) power plants could make coal an important source of hydrogen. Or, nuclear power could generate electricity to produce hydrogen via electrolysis or an alternative process.

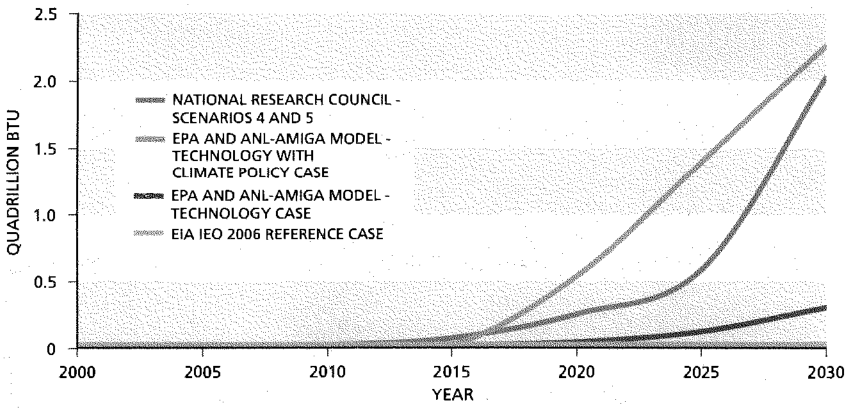
Clearly, many primary energy sources can be used to produce hydrogen. If hydrogen became the transportation fuel of choice, it could provide convergence between all sources of energy and remove the end-fuel issue from carbon policy discussions. Policy discussions might then focus on the primary sources of hydrogen, which, given its centralized nature, could more easily fit with carbon capture and sequestration.

Forecasts for hydrogen use (Figure 2-75) are usually limited to the United States. Business-as-usual forecasts, such as the EIA Reference Case, do not show significant growth in hydrogen use for transportation. By comparison, forecasts that incorporate rapid technology development and targeted carbon constraints show considerable growth in the U.S. market. However, even in this growth case, hydrogen does not displace petroleum-based transportation fuels during the study time frame.

Energy Conversion and Delivery Infrastructure

Key Observations—Energy Infrastructure

- *Energy forecasts generally do not explicitly account for specific energy infrastructure requirements, such as capital requirements, return expectations, construction schedules, resources, and permitting processes.*
- *Uncertainty relating to energy demand outlooks may restrict or delay infrastructure investment.*
- *Data collection and analysis of energy transportation infrastructure is inadequate for evaluating infrastructure capacity, throughput, and future needs.*
- *A significant realignment in the global refining system is underway, following forecast demand growth in China and India.*
- *Infrastructure requirements of many alternative energy sources at scale are not well understood and may be significant.*
- *Complex permitting processes lengthen infrastructure construction times and reflect social, environmental, and land-use constraints on infrastructure development.*



Sources: National Research Council, *Implications of a Transition to Hydrogen in Vehicles for the U.S. Energy System Scenarios*, 2004; Argonne National Laboratory, *AMIGA U.S. Technology Case Projections*, 2005; and Energy Information Administration, *International Energy Outlook 2006*.

FIGURE 2-75. *Projected U.S. Hydrogen Use for Transportation*

- *Implementing widespread carbon capture and sequestration will require significant new infrastructure.*

This section summarizes discussions in the Infrastructure and the Refining & Manufacturing Topic Papers on the CD distributed with this report.

The energy forecasts reviewed in this study do not show significant infrastructure development constraints other than those associated with siting and permitting nuclear power generation. Based on historical experience, forecasts generally assume that if sufficient economic incentive exists, new infrastructure will be developed or existing infrastructure expanded.

As with independent supply forecasts, a limited set of forecasts are available to assess new infrastructure requirements over a given period and supply-demand balance. These forecasts usually include capital and resource requirements, but focus on global or national scales that do not allow analysis of regional infrastructure development and requirements. In addition, considerably more infrastructure data are available for the United States than for the rest of the world, which increases the uncertainty of projections.

Growing international trade in natural gas and petroleum liquids will require the development of new infrastructure. For natural gas, the LNG supply chain will need considerable capital investment, from upstream development and natural gas liquefaction to LNG tankers and regasification facilities. Not all natural gas will be transported via LNG, so significant investments will also be required in long-haul natural gas pipelines. Similarly, the growing international trade in petroleum liquids will require considerable investment in oil pipelines and ocean tankers.

The evolving concentration of energy demand and energy production in different regions around the world will create new trade flows and associated infrastructure requirements. Limited infrastructure and energy trade routes that run through a few international choke points raise increasingly serious security risks (Figure 2-76).

Time and scale are significant considerations for energy infrastructure. The large, global infrastructure projects associated with forecast demand growth have long lead times. Building spare infrastructure capacity to deliver energy may not meet conventional economic thresholds. Therefore, potential project delays and lack of spare capacity increase the risk of temporary supply constraints.

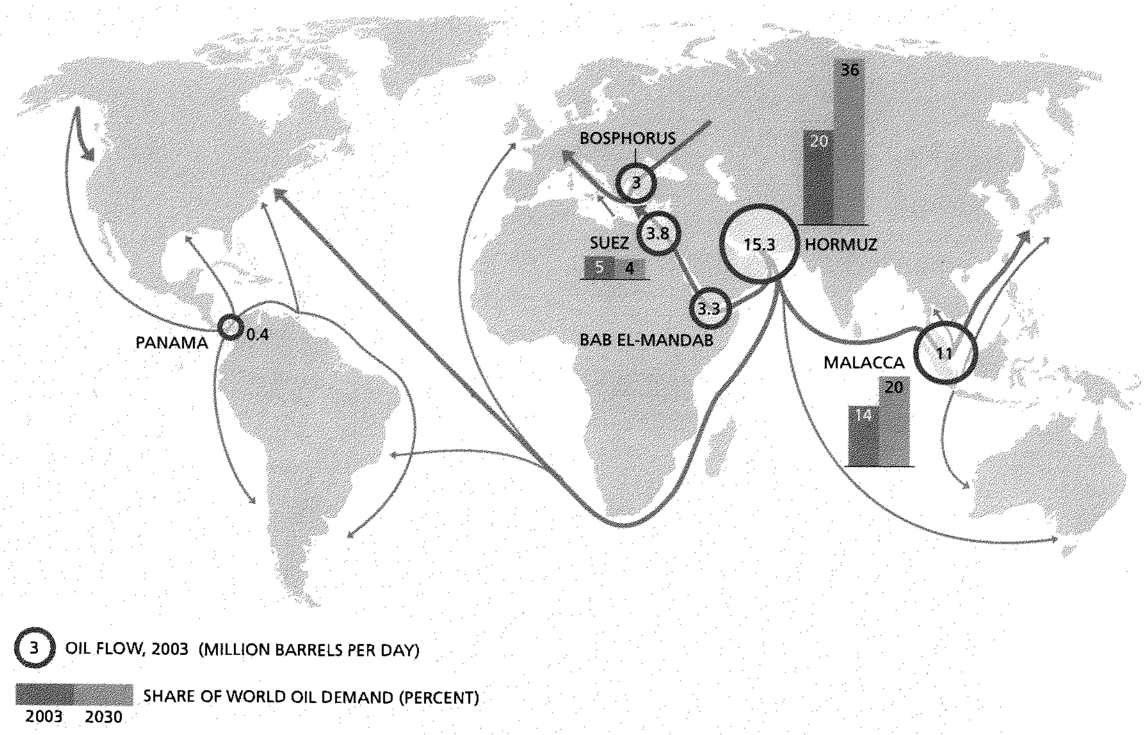
Transportation infrastructure is a highly complex, robust network that delivers energy and other commodities from resource locations to manufacturing plants and ultimately to consumption centers. The transportation system is an immense network of pipelines, railways, waterways, and roads that has been in continuous development for the past two centuries. Safe, reliable infrastructure has been, and will continue to be, a prerequisite for economic growth. Figure 2-77 suggests the complexity of the energy supply system.

In 2002, for example, more than 19 billion tons of freight was delivered across the transportation system. Energy commodities—coal, natural gas, crude oil, ethanol, and petroleum products—comprise nearly one-third (by weight) of the freight shipped in the United States. Freight shipments are expected to grow 72 percent to nearly 33 billion tons by 2030, while shipments of energy commodities are expected to total 11.4 billion tons. Pipelines, tankers/barges, and railways are the main transport modes for energy commodities. Roads are the primary delivery routes for transportation fuels from blending facilities to consumer filling stations.

A reliable, economic, and flexible energy transportation infrastructure is essential to national security and economic prosperity. Demands on current and anticipated infrastructure are heavy and growing, both to supply conventional forms of energy and enable diversification to new sources.

Refining and Manufacturing ◆

Petroleum refining capacity in the United States has changed significantly over the past 35 years. The rapid increase in capacity in the 1970s resulted from the combination of many factors, including incentives for small refiners (Figure 2-78). Coupled with reduced demand for products after the oil price shock in 1979, the incentives led to over-investment in small, inefficient refineries and poor margins for these investments. The last three decades have seen a rationalization of this inefficient capacity, while refinery outputs have increased at the same time. The number of refineries in the United States fell from more than 300 to 150 while the average capacity per refinery steadily increased, through efficiency gains and plant expansions. U.S. refinery output has



Source: International Energy Agency, *World Energy Outlook 2004.*

FIGURE 2-76. *Oil Flows and Geographic Choke Points, 2003*

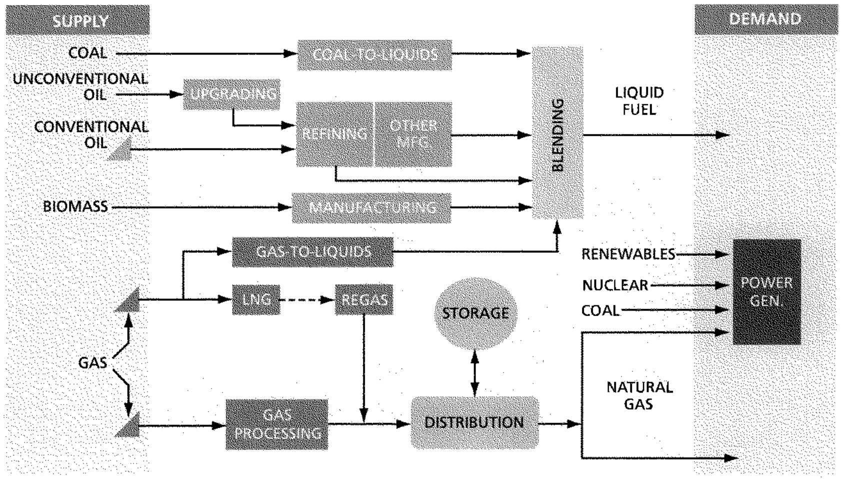
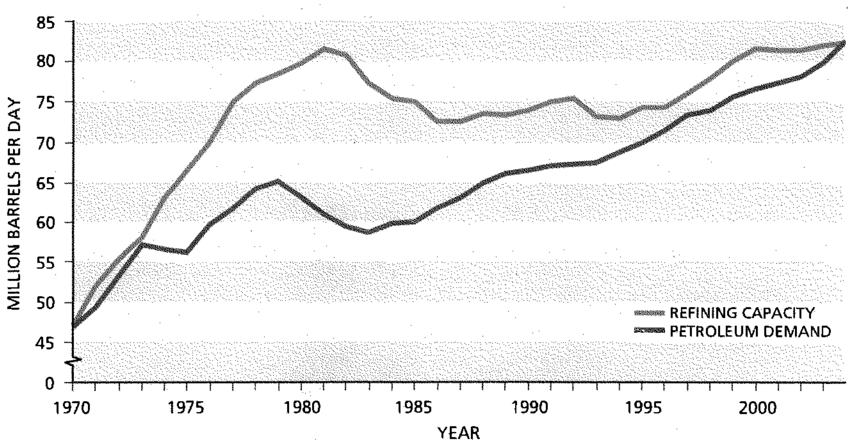


FIGURE 2-77. Simplified Infrastructure Diagram for Energy Production, Conversion, and Delivery



Sources: Refining Capacity: eia.doe.gov/international/iealf/table36.xls; **Petroleum Demand:** eia.doe.gov/emeu/ipsr/t46.xls.

FIGURE 2-78. Global Historical Refining Capacity

increased continuously since 1985, while capacity increased by 11.7 percent between 1996 and 2005.[17] However, domestic refining capacity has not been able to keep up with product demand, resulting in increased U.S. imports of finished product and blendstock.

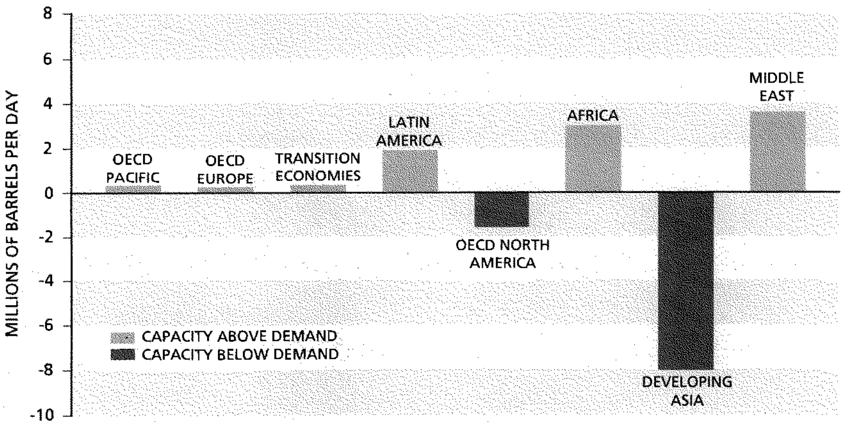
The study focused on four key questions to assess and understand global refining capacity projections over the next 25 years:

- What new refining capacity will be built over the next 25 years to process the projected crude oil demands?
- Where will the new capacity be located?
- What new technologies need to be developed to increase the capacity to process unconventional oil?
- What policies or regulatory barriers exist today that may inhibit development of new refining capacity?

Analysis of Refining Forecasts

Ten forecasts comprising 18 scenarios contained 27 direct or inferred projections for refining capacity. The primary integrated studies from the IEA and EIA were the context for assessing the refining capacity data from the other studies. Based on the IEA and EIA Reference Cases, global refining capacity must grow by 32 MB/D over the next 25 years to meet projected oil demand. The studies and cases reviewed in this study provide various projections based on different assumptions. However, *all* cases with a projection for 2015 show primary oil demand exceeding projected 2015 refining capacity, even assuming that all announced capacity expansion projects in the latest *Oil & Gas Journal Worldwide Construction Survey* are executed. The gap is consistent with the delicate balance between forecasted infrastructure demand and the uncertainty that governs it. Resolving the uncertainty around this projected imbalance can create incentives for additional projects to increase capacity.

Figure 2-79 is one projection of the balance between regional refining capacity and demand in 2030. Based on the IEA and EIA data, growing oil demand in the United States will continue to outpace rising refinery output, requiring continued imports of blending components and finished products. Europe, the Middle East, and Africa will



Source: Calculated from data in *Oil & Gas Journal 2005* and EIA *World Energy Outlook 2006*.

FIGURE 2-79. *Projected Balance between Regional Refining Capacity and Demand in 2030*

increase refining capacity above their oil demand, allowing export of finished products. Asia is projected to move from a balance between oil demand and refining capacity to an imbalance similar to the U.S. situation, with product imports needed to bridge the supply gap.

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[17] Federal Trade Commission Report, *Investigation of Gasoline Price Manipulation and Post-Katrina Price Increases*, Spring 2006.

Increased unconventional oil production, primarily from Canada, is unlikely to require new technology development for the refining industry. Existing residual oil conversion technologies, including coking and solvent de-asphalting, should be sufficient to process the heavy oil into finished products. The unconventional oil-to-products value chain is tightly integrated because unconventional oil is generally less fungible than lighter conventional oil. Refineries that make the investments required to process heavy crude oil will become increasingly complex, as they add capacity to convert residual heavy oil, supply additional hydrogen, and provide hydrotreating.

The increasing integration of biofuels into the refined products distribution system can complicate distribution logistics, increase transportation costs, and reduce supply reliability. The requirements for transporting biofuels have led to large shipments by rail and truck from bio-refineries to product distribution terminals. This represents a shift in the fuels transportation system from large, cost-efficient, bulk shipments by reliable and dedicated pipelines, barges, and ships to small, less cost efficient shipments by non-dedicated railroads. The shift may reduce supply reliability while increasing transportation costs. Efforts to incorporate biofuels into existing pipelines or construct new, dedicated pipelines for biofuels at significant cost are directed at overcoming such hurdles.

ACCESS TO RESOURCES ◆

Governments around the world have restricted access to oil and natural gas resources for various reasons, including to preserve wildlife habitat or fragile ecosystems or to further domestic economic and energy security. Recent studies in the United States have identified over 20 billion barrels onshore and nearly 19 billion barrels offshore of technically recoverable oil resources that are under access restrictions which prevent their development. This section summarizes restrictions in the United States and globally.

United States Onshore

A recent comprehensive review of U.S. oil and natural gas resources showed that almost 97 percent, or 20.5 billion barrels, of undiscovered technically recoverable oil resources beneath onshore federal lands are inaccessible or have restrictions beyond standard lease terms[18] (Table 2-10).

Over 60 percent of U.S. technically recoverable oil resources and 66 percent of U.S. technically recoverable

Study Area Onshore (including Alaska)	Area		Undiscovered Technically Recoverable Resources			
	Acres (x1,000)		Oil (Million Barrels)		Natural Gas (Billion Cubic Feet)	
Inaccessible or With Restrictions	75,452	76%	20,473	97%	161,647	87%
Standard Lease Terms	23,751	24%	743	3%	25,210	13%
Total	99,203	100%	21,216	100%	186,857	100%

Sources: U.S. Departments of the Interior, Agriculture, and Energy, 2006.

TABLE 2-10. *U.S. Onshore Oil and Gas Resources with Access Restrictions — Federal Lands*

natural gas resources lie beneath state, tribal, and private lands. Over the past several decades, urban growth, competing land uses, and changing public values have placed ever-increasing constraints on existing and new oil and gas development.

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[18] Scientific Inventory of Onshore Federal Land's Oil and Gas Resources and the Extent and Nature of Restrictions or Impediments to Their Development (EPCA Inventory), 2006.

Arctic National Wildlife Refuge

The Alaska National Interest Lands Conservation Act of 1980 established the Arctic National Wildlife Refuge (ANWR). In Section 1002 of the Act, Congress deferred a decision regarding management of the 1.5 million acre coastal plain, or 1002 Area, in recognition of its significant potential for oil and natural gas resources as well as its importance as wildlife habitat. Congress continues to debate whether to open this portion of ANWR to oil and gas leasing and exploration and to eventual development if economic oil and gas resources are discovered. Table 2-11 shows potential energy and economic impacts using USGS estimates for mean and high undiscovered crude oil resources in the 1002 Area.[19]

Marginal Wells

In 2005, marginal oil wells provided over 17 percent of oil and 9 percent of natural gas produced onshore in the United States. The nation has over 400,000 marginal oil wells, each producing 10 barrels or less of oil

	2020	2025	2030	Cumulative by 2030 (Million Barrels)
Production Rate (1,000 Barrels/Day)*				
ANWR 1002 Mean	539	723	576	3,054
ANWR 1002 High	741	1,175	1,062	4,812
				Cumulative by 2030 (Million 2005 Dollars)
Federal Royalties (Million 2006 Dollars)				
ANWR 1002 Mean	$1,487	$1,593	$1,587	$22,922
ANWR 1002 High	$2,044	$3,240	$3,012	$36,353
Federal Income Taxes (Million 2006 Dollars)				
ANWR 1002 Mean	$1,572	$1,503	$1,346†	$19,014
ANWR 1002 High	$1,997	$2,406	$2,040	$33,801

* These production estimates are lower that some previous estimates, such as those reported by the Energy Information Administration, because they only include development of resources on federal lands in the coastal plain and not potential resources on Native lands or state offshore coastal waters.

† Tax revenues in 2030 are lower than those in 2020, despite higher levels of production, because larger, more profitable fields were assumed to be developed before smaller, less profitable fields.

Source: Advanced Resources International, 2006.

TABLE 2-11. *Estimated Production, Federal Royalties, and Federal Tax Revenues Associated with the Leasing and Development of the Arctic National Wildlife Refuge (ANWR) 1002 Area*

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[19] *Potential Federal Royalty and Income Tax Revenues Resulting from the Leasing and Development of the Coastal Plain of the Arctic National Wildlife Refuge,* Advanced Resources International for U.S. DOE, 2006. Also see EIA, *Analysis of Oil and Gas Production in the Arctic National Refuge,* March 2004, SR/OIAF/2004-04. USGS surveys suggest between 5.7 and 16.0 billion barrels of technically recoverable crude oil are in the coastal plain of ANWR, with a mean estimate of 10.4 billion barrels that includes oil resources in Native lands and state waters out to a 3-mile boundary within the coastal plain. The mean estimate for the federal portion of the ANWR coastal plain is 7.7 billion barrels of crude oil. In comparison, the estimated volume of technically recoverable unproven oil in the rest of the United States was 136 billion barrels as of January 1, 2006.

	Undiscovered Technically Recoverable Resources	
	Oil* (Billion Barrels)	Natural Gas (Trillion Cubic Feet)
United States – Federal OCS	**17.84**	**76.47**
Gulf of Mexico	3.65	22.46
Atlantic	3.82	35.99
Pacific	10.37	18.02
United States – Other	**1.38**	**6.78**
Great Lakes	0.43	5.23
State Waters	0.95	1.55
Canada	**10.86**	**51.10**
Northern Canada	0.10	4.00
Nova Scotia	1.06	5.30
British Columbia	9.70	41.80
Total in Moratoria Areas	**30.08**	**134.25**

*Oil includes natural gas liquids. Does not include resources in areas already under lease.

Note: In January 2007, the presidential moratoria were lifted for the entire North Aleutian Basin and a small portion of the Eastern Gulf. Revised resource estimates were released by the Department of the Interior in May 2007 and this table reflects those revised estimates.

Sources: Department of the Interior, Minerals Management Service and U.S. Geological Survey; and Interstate Oil and Gas Compact Commission.

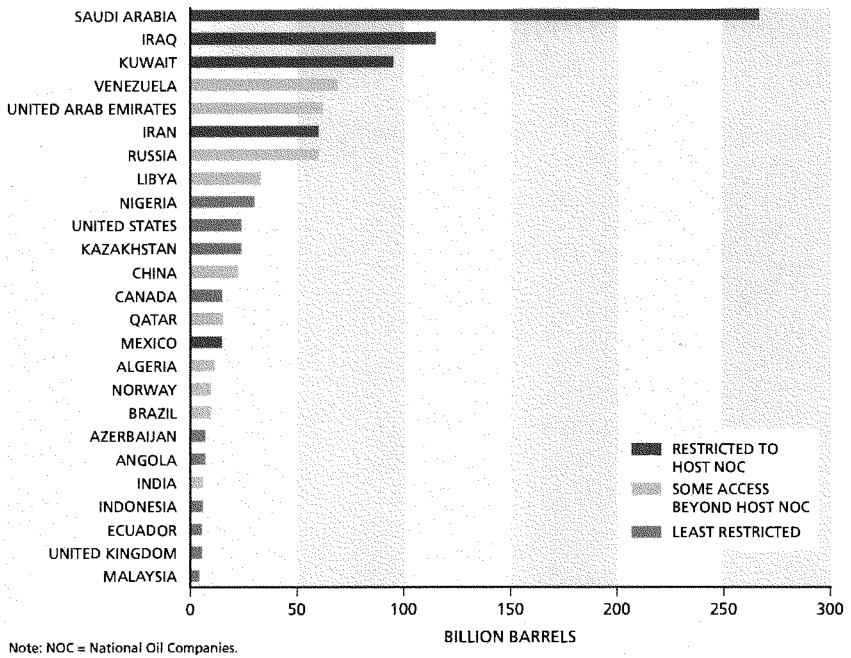
TABLE 2-12. *U.S. and Canadian Offshore Oil and Natural Gas Resources in Moratoria Areas*

Moratoria Area	Incremental Production by 2025		Cumulative Production through 2025		Cumulative Investment to 2025	Value of Avoided Oil Imports to 2025	Cum. Federal Royalties to 2025	Cum. Federal Inc. Taxes to 2025	Max. Direct Jobs	Max. Total Jobs
	Crude Oil (MMb/d)	Natural Gas (Bcf/year)	Crude Oil (Million Bbl)	Natural Gas (Bcf)	(Million $)	(Million $)	(Million $)	(Million $)		
Alaska: N. Aleutian Basin	0.02	49	89	901	$2,881	$4,871	$1,842	$1,132	2,221	8,577
Atlantic Offshore	0.17	382	480	3,717	$10,281	$21,090	$7,433	$5,115	25,447	57,090
Eastern Gulf of Mexico	0.26	379	480	2,084	$21,099	$35,790	$7,977	$5,893	40,838	78,039
Central Gulf of Mexico	0.15	294	690	3,788	$18,452	$34,273	$11,049	$7,884	19,239	70,440
Pacific Offshore	0.47	300	1,132	2,078	$26,714	$50,098	$12,937	$8,865	54,561	212,318
All Moratoria Areas	**1.01**	**1,394**	**2,758**	**11,748**	**$88,163**	**$145,472**	**$41,128**	**$28,285**	**139,604**	**426,464**

Note: Assuming MMS *mean* resource estimates and the January 2006 Congressional Budget Office price forecast (all estimates in 2006 dollars).

Source: Advanced Resources International, 2006.

TABLE 2-13. *Estimated Energy Supply and Economic Benefits from OCS Moratoria Areas*



Note: NOC = National Oil Companies.
Source: U.S. Department of Energy.

FIGURE 2-80. *Access to World Proved Oil Resources*

per day for an average 2.2 barrels per day. Without production from marginal wells, it has been estimated that U.S. oil imports would increase by nearly 7 percent.[20] Increasing operational and regulatory costs and diminishing access to markets via pipelines can contribute to the premature abandonment of marginal wells. When wells and fields are abandoned prematurely, the associated oil and gas resources may never be recovered due to economics, lease termination, and related issues.

North America Offshore

Approximately 30 billion barrels of undiscovered technically recoverable oil resources and 134 trillion cubic feet of undiscovered technically recoverable natural gas resources in offshore waters of the U.S. and Canada are in moratoria areas precluded by law or public policy from leasing and development (Table 2-12). Of these resources, about 18 billion barrels of oil and 76 trillion cubic feet of natural gas are currently off limits to leasing and development in the United States. There is significant uncertainty in resource estimates for those areas of the Outer Continental Shelf (OCS) subject to long-standing moratoria or presidential withdrawal. In the north, mid-, and south Atlantic, most of the west coast, and portions of the eastern Gulf of Mexico, the last acquisition of geophysical data and drilling of exploration wells occurred from 25 to 40 years ago. There were a few prospective discoveries at that time and numerous indications for the potential occurrence of oil and gas.

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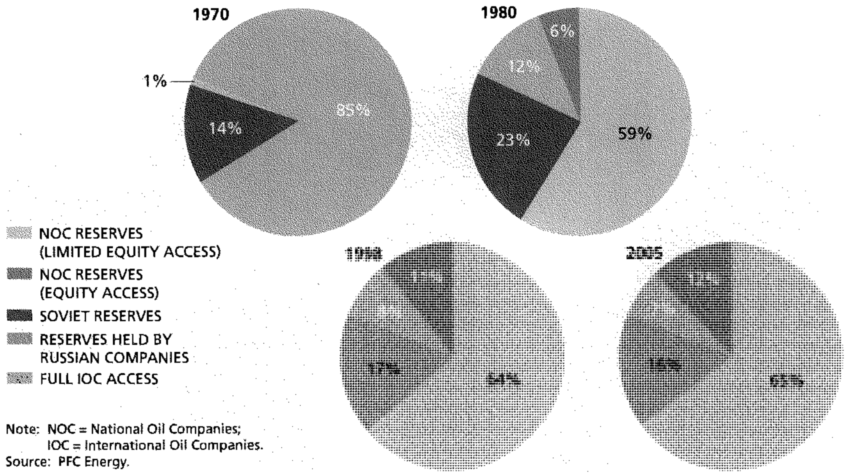
[20] Interstate Oil and Gas Compact Commission, *Marginal Wells: Fuel for Economic Growth*, 2006.



Note: NOC = National Oil Companies;
IOC = International Oil Companies.
Source: PFC Energy.

FIGURE 2-81. *Access to Global Oil and Gas Reserves over Time*

Estimates developed in 2006 show that the potential energy and economic benefits of increased access to oil and gas resources in OCS moratoria areas could be substantial (Table 2-13):[21]

- By 2025, U.S. crude oil production could increase by more than 1.0 MB/D.
- Nearly 2.8 billion barrels of crude oil could be produced between now and 2025—production that would not be realized if the existing moratoria were continued.
- Industry would spend $98 billion dollars in the U.S. by 2025 to develop these resources.
- Between now and 2025, the U.S. trade imbalance would be reduced by $145 billion if this domestically produced crude oil were to offset imports on a one-to-one basis.
- The U.S. would collect an additional $41 billion in royalties by 2025 from OCS production.
- An additional $28 billion in federal income taxes would be collected from OCS production between now and 2025.
- The economic activity generated by this development would result in the addition of as many as 130,000 direct domestic, high-paying jobs.

Global Access

Figure 2-80 shows access restrictions for resource holding countries in addition to the United States. Figure 2-81 shows how access to global oil and gas reserves has become increasingly restricted over time. The trend line and the proportion of resources under restricted access raise uncertainties about secure energy supply and potentially diminishing opportunities for equitable access.

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[21] *Estimate of the Potential Economic Benefits From the Leasing and Development of Oil and Gas Resources in OCS Moratoria Areas*, Advanced Resources International for U.S. Department of Energy, June 6, 2006. Based on mean MMS estimates of undiscovered oil and gas resources in the areas in question.

Chapter 3
TECHNOLOGY

Abstract

Technology contributes significantly to both reducing energy demand growth and expanding and diversifying supply. Technological advances to extend conventional and expand unconventional fossil fuels are examined, along with technology breakthroughs that may reduce the cost, mitigate environmental drawbacks, and increase the volume potential of alternative energy sources. However, a majority of the U.S. energy-sector workforce—including skilled scientists, engineers, and technicians—is eligible to retire within the next decade and these workers must be replaced and new workers trained.

This chapter examines how technology can significantly improve energy-use efficiency in transportation and other sectors, while also expanding the energy industry's ability to find and produce resources. Expert teams assess commercial and environmental opportunities for conventional and unconventional hydrocarbons, biofuels, nuclear, and other energy sources, noting the time frames needed to bring promising new technologies to market. They also consider ways government and industry can cooperate to renew the vital energy workforce.

The outline of the Technology chapter is as follows:

- Key Findings
- Technology Development and Deployment
- Personnel Issues
- Carbon Capture and Sequestration
- Conventional Wells (including EOR and the Arctic)
- Exploration Technology
- Deepwater Technology
- Unconventional Natural Gas Reservoirs—Tight Gas, Coal Seams, and Shales
- Unconventional Hydrocarbons: Heavy Oil, Extra-Heavy Oil, and Bitumen
- Unconventional Hydrocarbons: Oil Shale
- Unconventional Hydrocarbons: Gas Hydrates
- Coal to Liquids
- Biomass Energy Supply
- Nuclear Outlook and Its Impact on Oil and Gas
- Transportation Efficiency.

The oil and natural gas industry has a long history of technological advancement, and today operates using materials, sensors, chemistry, and engineering that are marvels well beyond the limits envisioned by industry pioneers or, indeed, the general public (Figure 3-1). Many technical advances have been generated directly by research and development (R&D) in industry labs, through field trials, and by applied ingenuity.

Globally, the industry spends more than $6 billion annually on oil- and gas-related R&D. This spending is on the upswing, which will result in technological advances we can only imagine today. The percentage

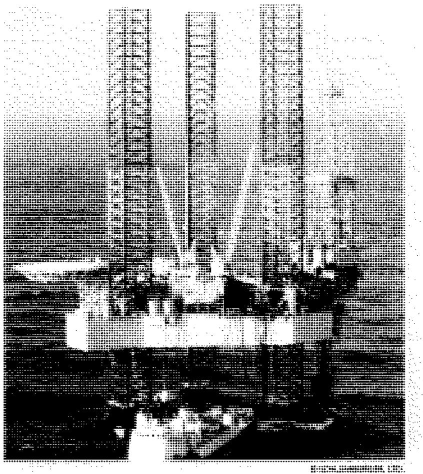

FIGURE 3-1. Jackup Rig with Fracturing Stimulation Vessel in the Gulf of Mexico

of that $6 billion that is focused on U.S.-specific needs is relatively small. R&D dollars, like capital expenditures, follow the most attractive opportunities, and these are increasingly found overseas. However, the U.S. industry has had some dramatic successes that point the way forward, confirming that there is a continuing role for the U.S. government in this area.

Deepwater technology, which has allowed us to tap into resources in the Gulf of Mexico at water depths exceeding 1,000 feet, is far greater than was imagined even a few years ago, and has significantly increased U.S. reserves and production. Coalbed methane, long considered a hazard to miners, is now a significant resource thanks to technology specifically applied after the U.S. government encouraged its development. In both of these cases, technology was not developed by U.S. government funding, but by industry pursuing opportunities and access to resources, which has made and continues to make a significant difference.

Government policy can affect how technologies are developed and implemented. For example, opening new areas for exploration stimulates R&D in technologies required to exploit those resources. Similarly, technologies that require new facilities, such as coal-to-liquids conversion plants or nuclear power plants, depend on establishing permitting and regulation procedures.

Several specific technologies highlighted in this chapter have potential for industry-government cooperation. These include advanced materials research in nanotechnology and in materials that can sustain high temperatures and high pressures, robotics, and metocean research.[1]

Enhanced oil recovery and carbon capture and sequestration (CCS) are activities for which significant advances are expected in the coming decades. Today, technology is developing to reduce the cost of separating carbon dioxide (CO_2) and to sequester large amounts of the gas in deep underground formations. Beyond today's biofuels, research breakthroughs are expected in second-generation crops and cellulosic ethanol production.

Advancements are being achieved by the industry that reduce environmental impacts, particularly in fragile and ecologically sensitive locations. "Greener" chemicals are being deployed throughout operations. Further cost reductions and technology to reduce environmental effects will be applied in heavy-oil reservoirs and later in oil shales in the western United States and elsewhere. Water and other resource demands increase significantly with many of these new developments, however, and in some regions these demands may become the largest factor limiting growth.

Clearly, a significant piece of the overall energy puzzle will be technology that increases the efficiency of energy use. This is an area rich in opportunity for both technology advancements and policy measures. It is, however, an area complicated by consumer preferences and diverse situations for technology's adoption. One can see this in the evolution of the U.S. auto fleet over the past decade, where technical improvements in drive-train efficiency have been mainly applied to increase performance rather than fuel economy. As with technology developments to increase supply, clear regulatory signals by governments and economic opportunities by the private sector combine to accelerate technology advances. The U.S. refrigerator efficiency standard, which raised efficiency requirements and reduced energy consumption, is a good example of a clear success that could be duplicated. Lighting, building-energy efficiency, and electricity-grid improvements are all areas where ingenuity combined with smart policy would yield big efficiency gains.

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[1] Nanotechnology includes devices and materials whose size is in the range of 1 to 100 nanometers (billionths of a meter). Metocean is the "weather" of the offshore environment both above and below the surface of the water. The word is a contraction of "meteorology" (weather in the air) and "oceanology" (conditions below the surface of the water) and is used by all offshore industries.

While current R&D by the oil and natural gas industry, along with entrepreneurial start-ups funded by increased venture and equity capital, is on the upswing, U.S. government funding for oil and natural gas research is trending down. Department of Energy monies have been a significant funding source for U.S. universities and national laboratories. This funding is particularly important, as it enables students to pursue advanced degrees that are relevant and vital to our country's energy future. One of the most significant issues facing the U.S. energy industry is a critical shortage of engineers and scientists. This stems from the cyclical nature of the industry and by public perceptions, as well as reductions in the number of U.S. petroleum and geoscience degree departments, and industry demographics. More than 50 percent of the industry's current technical workforce is eligible for retirement within the next decade, creating an experience and skill shortage at a time when demand will be increasing. Solving this challenge will require cooperation among federal and state governments, academia, and industry if the United States is to continue its historical leadership in oil and natural gas technology development.

Topics are arranged in six broad groupings in this chapter. The first group contains two topics that are part of all the others—technology development and personnel issues—and one that is likely to be important for many of the others—carbon capture and sequestration. The second group describes exploration and production (E&P) activities that are current today: conventional resources (including enhanced oil recovery and arctic activities), exploration, and deepwater technologies. The third group comprises unconventional natural gas production in shale gas, coalbed methane, and tight gas sands (reservoirs with extremely low permeability). The fourth group includes unconventional hydrocarbon sources in heavy oil, oil shale, and methane hydrate. The fifth group describes alternative sources for liquid fluids from coal and biomass. The final group has two reports covering the effect that nuclear technology might have on the oil and natural gas sector, and the impact that technology improvements might have on transportation efficiencies.

Each section includes a description of the technology topic, information about the state-of-the-art within the topic, and, in many cases, the most important developments expected by 2010, 2020, and 2030. Details and technical discussions can be found in the individual Technology Topic Reports that are available on the CD that accompanies this report.

KEY FINDINGS

- The current and projected demographics of trained personnel in the broad U.S. energy industry indicate a shortage that is expected to worsen due to retirements in the next decade and beyond. The shortage affects both the E&P part of the business (upstream) and the refining part (downstream), construction, and other sectors, including the transportation industry. It ranges from skilled craftspeople through PhDs. Fewer academic departments are training students in petrotechnical areas now than in the 1980s. However, the problem is wider, with shortages of students in science, engineering, and mathematics. A similar situation exists for craft labor.
- Carbon capture and sequestration underground will facilitate the continued use of fossil fuels in an increasingly carbon-constrained world. CCS is technically achievable today, and has been demonstrated at a project level and applied in enhanced oil recovery. However, CO_2 has not been injected at the scales (both volumes and time periods) that will be necessary in the future.
- The prospect for advancements in technology is very good, but the Technology Task Group found no single, simple solution with the potential to provide energy security for the United States over the long term. The solution will involve as many of the available resources and potential technologies as can be developed and deployed.
- Technology can significantly improve transportation efficiency, particularly for light duty vehicles. Consumer preferences affect the deployment of technology in that sector, whereas a sound business case affects deployment in the other transportation sectors.

- Technology has had a significant impact on the industry's ability to find and produce resources. In exploration, 3D seismic technology created a boom in activity starting in the 1980s, driving down acquisition costs while improving the exploration success rate. In another area, after government policies were enacted in the 1980s, technologies were developed to understand and exploit coalbed methane, a resource that has been known since the beginning of the coal mining industry (Figure 3-2).
- Access to acreage with potential for economic oil and natural gas resources is itself a primary driver that encourages technology development. The onset of area-wide leasing for the U.S. Gulf of Mexico in the early 1980s led to significant acceleration of interest in deepwater regions.
- Commercializing technology in the oil and gas market is costly and time-consuming; an average of 16 years passes from concept to widespread commercial adoption.
- Recovery from existing and future resources is expected to improve because of continuing increases in the volume of the reservoir that is in proximity to a wellbore, thanks to both close well spacing and improved technologies such as multilateral horizontal wells. Environmental impact will continue to be reduced as technology allows operations with a smaller "footprint" and "greener" chemicals.
- Improved exploration and exploitation technology slowed the decline in discovery volumes. Although the future of exploration technologies is bright and the exploration success rate may continue to improve, it is still likely that the volumes of hydrocarbons discovered with time will continue to decrease.
- Unconventional natural gas resources in tight gas sands, coalbed methane, and gas shales have become commercial because of technological advances, and these new resources are likely to continue to be important.
- Technologies are available for production of heavy oil, extra-heavy oil, and bitumen, but these heavier crudes are in less demand than conventional oil because of the difficulty in processing to create refined products, and because fewer refineries have the capability to process them (Figure 3-3).
- Oil shales may become a commercial resource by 2020, although large-scale production is unlikely

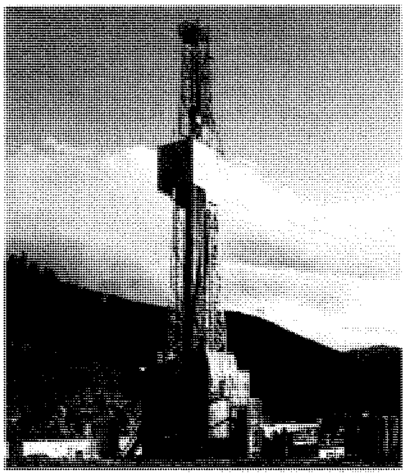

FIGURE 3-2. *Land Rig in the Rocky Mountains*

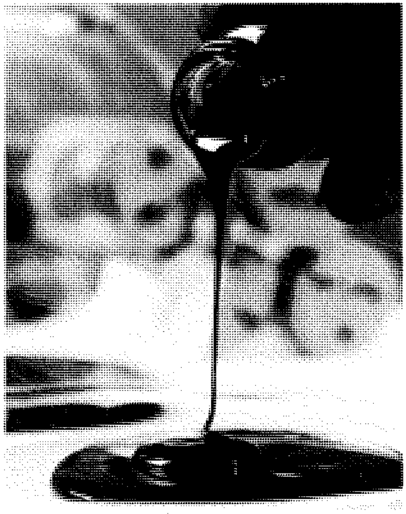

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FIGURE 3-3. *Heavy Oil Sample*

until 2030. The technique used historically is surface processing in a high-temperature retort. An alternative process still in development, in situ conversion at lower temperature, has captured the industry's attention. In situ conversion technology is just emerging, so it is not yet clear which specific technologies can advance the state of the art over the coming decades.

- An economically viable method for production of natural gas from naturally occurring hydrate resources has not been developed. Hydrate sites are known to be in arctic areas, and in some marine locations in other parts of the world, but no efforts have been made to locate commercial marine deposits of hydrates in U.S. waters.
- Estimates for coal-to-liquids production are small relative to the overall petroleum market through 2030, for cost and environmental reasons.
- Biofuels face technological and logistics challenges before becoming a more significant part of the U.S. transportation fuel mix. Still required are efficient and scalable conversion techniques for cellulosic materials such as switchgrass, corn stover, and woody biomass; efficient transportation networks from field to plant; and ways to overcome water-supply shortages.
- Nuclear power plants provide base-load electrical power, whereas electricity generated using oil or natural gas is typically load-following. Therefore, if developed in the United States, growth of nuclear power will displace a much greater amount of coal-powered generation growth and a smaller amount of oil and natural gas generation.
- With many mature, marginal fields, the United States has specific R&D needs that have a lesser focus for the largest industry R&D organizations than the more prolific international prospects.

TECHNOLOGY DEVELOPMENT AND DEPLOYMENT

Since the beginning of the modern age of oil and natural gas, technology has played a fundamental role in supporting the efficient production of hydrocarbons. Oil and natural gas technologies are often destined for hostile, hard-to-reach environments such as deep offshore waters or in the high temperatures and pressures encountered at the bottoms of wells. Full-scale tests must be completed before a technology can be proved and the market will accept it. As a result, commercializing technology in oil and natural gas markets is costly and time-intensive; some studies indicate an average of 16 years from concept to commercialization. The Technology Development Topic Report examines both lessons from history and current trends in oil and natural gas technology development and deployment to make predictions for the coming years.

The sources of technology destined for the oil and natural gas markets have changed over time. Starting in the early 1980s, major oil and natural gas companies began to decrease their R&D spending, driven in large part by a decision to "buy versus build" new technology. Historically, independent oil and natural gas companies have spent little on R&D. Service companies have stepped in to partially fill the gap by increasing their R&D spending. There is little doubt that in the coming years, new technologies will be invented and applied to the global quest to maximize production from oil and natural gas reservoirs. As oil prices have risen over the past few years, so have R&D budgets, with the exception of U.S. government spending. The global industry will spend more than $6 billion on R&D, much of it in areas outside the United States.

The major oil and natural gas companies follow the best investment opportunities, including R&D, which are increasingly found overseas. This pursuit leaves U.S. onshore production largely in the hands of independent oil and natural gas companies. In a global marketplace, the service companies continue to respond to the needs of their worldwide customer base.

Being one of the most mature oil and natural gas producing countries, the United States has specific technology requirements compared with much of the rest of the world (Figure 3-4). More than 400,000 U.S. oil wells produce less than 10 barrels a day (of these, the average national production is 2.2 barrels per day). About 289,000 marginal natural gas wells produce less than 60 million cubic feet a day in the United States (an average of 16.7 million cubic feet per day per well). That is 17 percent of the oil and 9 percent of natural gas produced onshore in the United States.[2]

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[2] Interstate Oil and Gas Compact Commission, "Marginal Wells: Fuel for Economic Growth" (2006).

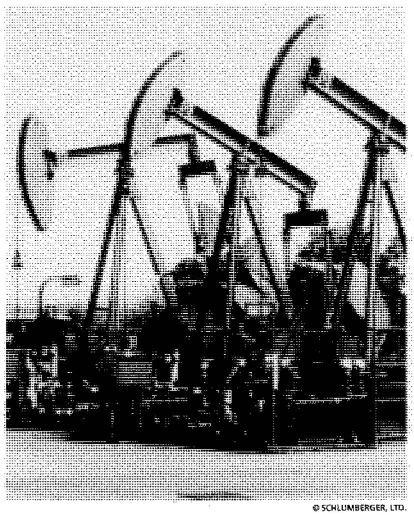
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FIGURE 3-4. *Pumping Units that Produce Oil from Low-Pressure Reservoirs*

Research is key to the survival of these marginal wells. Unfortunately, the small, independent producers who operate these wells rarely have the ability to conduct research, even though R&D might keep them producing for many more years. As a result, unless the technology requirements of the U.S. oil and natural gas business align with the needs of the rest of the world, there is a danger that U.S. interests may not be addressed adequately.

Figure 3-5 shows U.S. government R&D funding in recent years, split between oil and natural gas.[3] Research undertaken by national laboratories and universities usually leads to fundamental understanding and basic technologies. These technologies are typically applied by other entities such as oil and natural gas, service, or start-up companies.

However, the U.S. government proposal for fiscal year 2007 to terminate the oil and natural gas program within the Department of Energy leaves only $50 million in royalty receipts that were set aside in the Energy Policy Act of 2005. The bulk of the funds ($35 million) is set aside for ultra-deepwater and

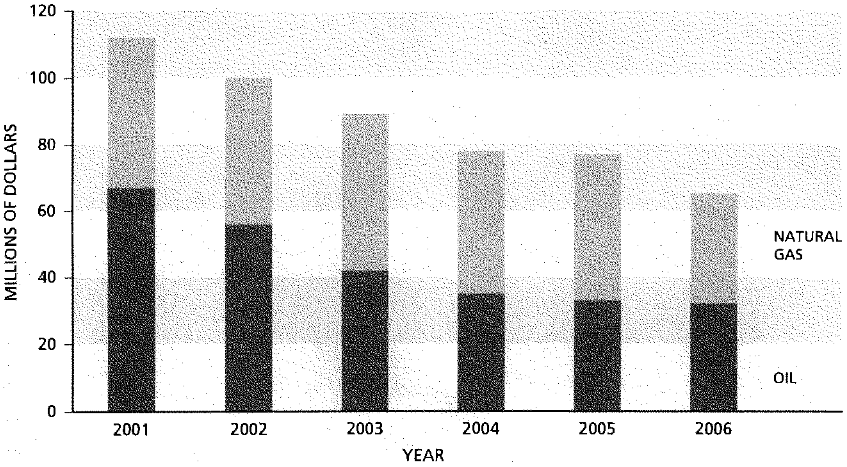

FIGURE 3-5. *Oil and Natural Gas R&D Funds Provided by the U.S. Government*

unconventional-hydrocarbon research programs as part of the Research Partnership for a Secure Energy America (RPSEA). The remainder ($15 million) is set aside for an internal National Energy Technology Laboratory program and administrative funds.

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[3] Lawson, William F, "Who Will Fund America's Energy Future?" Interstate Oil and Gas Compact Commission report (2006).

Many successful research programs have featured accountability as a key attribute. Examples show that it is possible to leverage funding, such as the Ansari X prize for privately funded manned space flight, the Orteig prize to Lindbergh for his solo flight across the Atlautic, and the Board of Longitude prize for the 18th century invention of the marine chronograph that enabled navigators to determine longitude at sea.

PERSONNEL ISSUES ◆

The exploration and production industry is currently in a boom cycle after an extended bust that lasted about 20 years. The current and projected demographics of trained personnel in the broad U.S. energy industry are disturbing, leading to a shortage that is expected to worsen and last for decades. This problem is pandemic, affecting upstream and downstream, construction, and other sectors including the transportation industry (Figure 3-6). Personnel shortages range from skilled craftspeople through PhDs. Within the E&P industry, the impending retirement and handoff to the next generation of employees has been referred to as the "big crew change;" the U.S. Department of Labor refers to it as the "demographic cliff."[4]

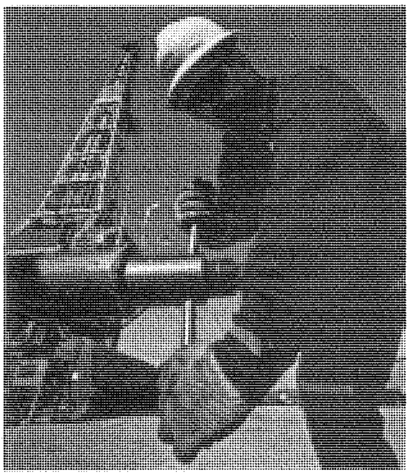

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FIGURE 3-6. Skilled worker on rig site

The majority of industry professionals are less than ten years from retirement eligibility. There are fewer academic departments in petrotechnical areas now than before the bust, and significantly fewer petrotechnical students are being trained to replace upcoming retirees. The industry's cyclical nature and its negative public image have kept the number of interested students low. Enrollment in petroleum engineering and geoscience departments of U.S. universities is down about 75 percent from its 1982 peak. However, the problem is wider, with a shortage of students in science, engineering, and mathematics. A similar situation exists for craft labor, with aggregate demand exceeding supply by an increasing margin over the next few years. Competition from other industries will intensify the shortage of personnel, which is exacerbated globally by an explosion in the rate of hiring by the industry in the past two years.

A study by Schlumberger Business Solutions in 2005 indicated a surplus of petrotechnical graduates in parts of the world, including Indonesia, Venezuela, and China, that is available to supply the areas with a deficit of graduates, such as the United States. However, a 2006 follow-up survey showed that the rapid increase in hiring has swamped even the ability of those countries to fill global needs. Even if the high rate of hiring lasts only a few years, language, culture, and immigration quotas pose barriers to a rapid flow of graduates from one part of the world to another.

Many E&P industry jobs can be (and are) filled by graduates of other engineering and scientific disciplines. However, the public's negative image of the industry makes recruiting those graduates difficult as well. The alternative of mid-career hiring is a negative-sum game when viewing the industry as a whole: although it helps one company, it does so to the detriment of another, and it is an expensive option.

Many of the Technology Task Group Topic Reports noted this problem as a barrier to implementing technological advances. For example, enabling development of coal-to-liquids technologies requires additional coal miners, transportation crews, and plant personnel, both skilled and professional. Similar problems are noted for any substantial increase in biofuels production, shale oil development, carbon sequestration, and other areas.

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[4] U.S. Department of Labor, "Identifying and Addressing Workforce Challenges in America's Energy Industry," President's High Growth Job Training Initiative, U.S. DOL Employment Training Administration (March 2007).

CARBON CAPTURE AND SEQUESTRATION

It is likely that the world is moving into an era in which carbon emissions will be constrained. For a general discussion on carbon, see Chapter 5, "Carbon Management." Oil and natural gas contribute more than half the current, energy-related CO_2 emissions. In a carbon-constrained world, the use of oil, natural gas, and coal will be affected by policy measures to reduce carbon emissions. Carbon management will involve combining several measures to reduce CO_2 emissions, including improvements in the efficiency of energy use and the use of alternatives to fossil fuels such as biofuels, solar, wind, and nuclear power. However, to meet the energy demands of the nation, the United States will continue using fossil fuels, including coal, extensively over the next 50 years or more. To do so, and to extend the resource base to include unconventional hydrocarbons such as heavy oil, tar sands, and shale oil, it will be necessary, if carbon constraints are imposed, to capture and sequester a large fraction of the CO_2 produced by burning these fossil fuels.

Carbon capture and sequestration entails trapping CO_2 at the site where it is generated and storing it for periods sufficiently long (several thousand years) to mitigate the effect CO_2 can have on the Earth's climate. In this report, we only consider geological sequestration and do not discuss possible alternatives, such as deep-sea sequestration, which is fraught with environmental concerns and issues of public acceptance. Geological sequestration would target spent oil and natural gas reservoirs and deep saline formations; the potential capacity is discussed in the CCS Topic Report.

The technologies required for effective CCS are, by and large, viable. Projects continue at Sleipner field, the Weyburn enhanced oil recovery (EOR) project in Canada,[5] and the In Salah saline formation project in Algeria.[6] The hurdles to implementation are largely ones of integration at scale. Current possible scenarios of climate change predict that by 2030, the level of CO_2 to be mitigated could be 30 billion tons per year or more.[7, 8] Sequestering 5 billion tons of CO_2 each year would entail pumping volumes close to 100 million barrels per day of supercritical CO_2 into secure geological formations. This amounts to around a quarter of the volume of water currently pumped worldwide for secondary oil recovery. At the local level, sequestering CO_2 from a 1-gigawatt coal-fired power station would require pumping into the ground some 150,000 barrels per day of supercritical CO_2.[9] A power station of that size would generate electricity for about 700,000 typical American homes.

While the technologies for CCS are essentially available, in that capture and storage can be implemented now, extensive scope remains for improvement. In particular, the capture stage of CCS is key, and currently dominates the overall cost. Novel, lower-cost approaches to capture would have a significant effect on the implementation of CCS and would, in turn, greatly influence the usability of fossil fuels under carbon constraint. The CCS Topic Report discusses other areas where continued research is important:

- Fundamentals of storage, such as long-term physiochemical changes in the storage reservoir
- Characterization and risk assessment (faults, cap rocks, wells)
- Reservoir management for long-term storage
- Integration of fit-for-purpose measurement, monitoring, and verification
- Ability to inject CO_2 into formations
- Retention and leakage, such as leakage through wells.

It is also crucial at this stage to undertake an assessment of the total U.S. capacity for CO_2 sequestration.

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[5] Wilson M, Monea M. (Eds.), IEA GHG Weyburn CO_2 Monitoring & Storage Project Summary Report 2000-2004 (2004).

[6] Riddiford, F, Wright, I, Espie, T, and Torqui, A, "Monitoring geological storage: In Salah Gas CO_2 Storage Project," GHGT-7, Vancouver (2004).

[7] Pacala and Socolow, "Stabilization Wedges: Solving the Climate Problem for the next 50 Years with Current Technology," *Science* 305 (13 Aug. 2004): 968.

[8] Third Assessment Report – Climate Change 2001, Intergovernmental Panel on Climate Change.

[9] Socolow, R, "Can We Bury Global Warming?" *Scientific American* (2005).

While it is reasonable to expect that the combined capacity of existing hydrocarbon reservoirs and deep saline formations is large, a detailed understanding of the regional distribution of capacity throughout the United States is critically important.

It is important to note that there is no experience available with full-process integration, e.g., a coupled, large-scale coal-fired power plant with CCS. Several projects worldwide, most notably FutureGen in the United States and Zero-Gen in Australia, are in the process of designing and constructing an integrated large-scale power and CCS operation. Operating such facilities successfully is central to understanding the true economics and practical requirements for large-scale CCS.

Experience Basis	Significance	Limitations
CO_2 enhanced oil recovery (EOR)	> 30 years experience; injection >= 1 million tons CO_2/year	Very limited monitoring programs; questions of applicability of experience to saline formations
Acid gas injection	> 15 years experience injecting CO_2 and H_2S into over 44 geologic formations	Generally small volumes; very little publicly available technical information
Hazardous waste disposal/ underground injection control	----	Most hazardous waste is not buoyant or reactive
Natural gas storage	~100 years experience injecting natural gas into rocks	Limited monitoring; different chemistry; built for temporary storage
Natural analogs	Several large (> 50 trillion cubic feet) carbo-gaseous accumulations globally; proof of concept	Most at steady state, transient knowledge unavailable; limited geography and geology
Conventional oil and gas E&P	Nearly 150 years of technology and experience in predicting and managing buoyant fluids in crust	Hydrocarbon recovery has goals and needs which differ from those of carbon sequestration
Capture/gas separations technology	> 70 years separating CO_2 and other acid gases from gas streams, including at power plants	Costs still higher than preferred under widespread deployment; still no integration of large power plants with CCS
Large CO_2 storage projects	3 large-scale projects; > 8 pending before 2010	Still limited monitoring programs; limited geologic representation
CO_2 pipelines and transportation	> 30 years experience at large scale; existing regulations likely to apply	None

TABLE 3-1. *Basis for Experience Relevant to Commercial Carbon Capture and Sequestration*

One activity in which CO_2 is pumped into reservoirs currently is enhanced oil recovery. This provides a proving ground for various techniques that are relevant to CCS, and can be implemented while other carbon-management solutions are under development. (A section of the Topic Report discusses the role of CO_2-EOR in the development of CCS technologies.) At present, CO_2-EOR is not directed towards effective storage of CO_2 but the techniques can be modified to improve carbon sequestration.

There is a growing scientific consensus that anthropogenic CO_2 is driving detrimental climate change.[10] Moreover, the Intergovernmental Panel on Climate Change (IPCC) Special Report on CCS indicates that including it in a mitigation portfolio could help stabilize CO_2 concentrations in the atmosphere (at double the pre-industrial level) with a cost reduction of 30 percent or more, compared to other approaches.[11] More recently, the UK's Stern Review estimated that the cost of meaningful mitigation—maintaining atmospheric levels of CO_2 at no more than double the pre-industrial levels—would amount to about 1 percent of global GDP. [12] Doing nothing, on the other hand, would likely incur a cost greater than

Technology	Significance	Brief Discussion
CO_2-EOR	Natural arena for exploring CCS	Provides a direct commercial incentive to pumping CO_2 into a reservoir
Evaluation of CCS in association with coal-fired plant	Development of integration of required technologies	Projects in United States, Australia, and China to develop CCS with coal plants
Improved capture technologies	Key determinant of cost of CCS	Significant efforts in United States, Europe, and Japan to drive down cost of capture
Injection of CO_2 into subsurface formations	Demonstration of injection and test of storage	CO_2 currently injected at the million tons/year level
Development of models for subsurface migration of CO_2	Understanding of migration behavior underpins characterization and MMV	Combination of modeling and experiment (e.g., Sleipner) to establish CO_2 migration
Reservoir characterization for storage	Reservoir characterization techniques migrate to CO_2 storage estimates	Available techniques tested at several sites
Measurement, monitoring and verification (MMV)	Available MMV technologies applied to CO_2 injection and storage	Available techniques tested at several sites
Development of CO_2 resistant cements	Primary leakage path is likely to be existing wells	Improvements in resistance of cements to corrosion are currently being pursued

TABLE 3-2. *Summary of Carbon Capture and Sequestration Technologies in Priority Order*

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[10] Oreskes, N, "The Scientific Consensus on Climate Change," *Science* 306 (3 Dec. 2004): 1686.

[11] "IPCC Special Report on Carbon Dioxide Capture and Storage," Intergovernmental Panel on Climate Change, Interlachen (2005), available at http://www.ipcc.ch/.

[12] "The Stern Review of the Economics of Climate Change," available at http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm.

Technology	Significance	Time Frame
Extensive CO_2-EOR with substantial CO_2 sequestration	Enhanced security of supply through better recovery	2010
Measurement, monitoring and verification (MMV) techniques	Necessary prerequisite for implementation	2010
Site characterization and risk assessment	Determination of site suitability for sequestration	2010
CO_2 leak remediation technology	Necessary for implementation of CO_2 storage	2010
Demonstration of coal-fired power with CCS	Establish precedent for the technology	2010
Assessment of U.S. CO_2 sequestration capacity	Primary requirement for siting power stations	<2020
Novel, inexpensive capture technology	Key cost determinant of CCS	<2020
Next-generation CO_2-EOR with maximum CO_2 storage	Increases usable CO_2 storage capacity in structurally confined geologic settings by three- to ten-fold	2020
Ubiquitous coal-fired power with CCS	Extensive power generation without CO_2 emissions	2030
Rig-site or sub-surface hydrocarbon processing to generate low-carbon fuels or feedstocks and recycle CO_2 within the reservoir or field for EOR followed by CCS	Keeps most of the carbon in or near the reservoir, simplifying CCS logistics and costs, enabling low carbon fuels/heat/power from oil and gas	2050

TABLE 3-3. *Summary of Carbon Capture and Sequestration Technologies in Time/Priority Order, with Time Frame to Commercial Use*

5 percent of world GDP, with a worst-case estimate of 20 percent, to ameliorate the damage caused by a deteriorating climate. These studies indicate that the financial risk to the nation of delaying action is now so high that a concerted emphasis on CCS is already strongly warranted.

Summary: Technical Issues

Tables 3-1, 3-2, and 3-3 describe the basis for experience relevant to commercial CCS, current technologies in priority order, and future technologies in time/priority order, with time scales to commercial use.

Technology today is well-understood and effective and can probably deliver what is needed. However, there are some outstanding technical issues:

- Novel, lower-cost capture technologies
- Integration and fit-for-purpose deployment of monitoring and verification
- Well-leakage characterization and mitigation
- Protocols for site characterization
- Technical basis for operational protocols and risk characterization.

Summary: Nontechnical Issues

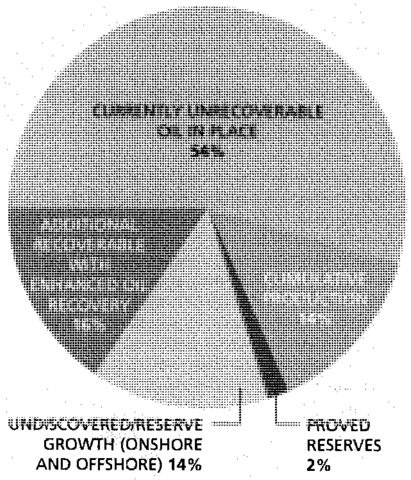
Given the scope of commercial CCS, there are many issues that are not technical, per se, but relate to technical readiness and ways to maximize early investment:

- There is a high likelihood of a critical gap in human capital. Currently, workers who can execute CCS are the same as those employed in oil and natural gas exploration and production. In a carbon-constrained economy, there will not be enough skilled workers to go around. This is particularly true for geoscientists, but also true for chemical and mechanical engineers.
- Development of a comprehensive set of energy policies and strategies is critical to provide certainty to make investment decisions.
- The legislative and regulatory framework within which CCS is conducted will have a major impact on how rapidly the technology is implemented and ultimately will determine whether CCS can effectively mitigate carbon emissions and provide access to future hydrocarbon supplies. A section of the CCS Topic Report is devoted to regulatory issues and details the various aspects of regulation that will be critical to the success of CCS.
- It is not clear that the science and technology programs in place today will provide answers required by regulators and decision makers. Greater dialogue between individuals working with technology and those developing a regulatory framework would help to reduce unnecessary regulation and guide R&D goals toward the most immediate needs.
- Infrastructure to transport CO_2, such as pipelines, is essential for commercial deployment. However, there is concern that pipelines for early project opportunities will not be able to carry additional future projects. Incentives and government action for this infrastructure can help to build networks sufficient to support large-scale, commercial CCS deployment in the United States.

CONVENTIONAL WELLS (INCLUDING EOR AND IN THE ARCTIC)

Large volumes of technically recoverable, domestic oil resources—estimated at 400 billion barrels—remain undeveloped and are yet to be discovered, from undeveloped remaining oil in place of over a trillion (1,124 billion) barrels (Figure 3-7). This resource includes undiscovered oil, stranded light oil amenable to CO_2-EOR technologies, unconventional oil (deep heavy oil and oil sands), and new petroleum concepts, such as residual oil in reservoir transition zones. As the leader in EOR technology, the U.S. oil industry faces the challenge of further applying this technology towards economically producing the more costly remaining domestic oil resources.

While pursuing this remaining domestic oil-resource base poses considerable economic risk and technical challenge to producers, developing the technical capability and infrastructure necessary to exploit this resource reduces our dependence on foreign energy sources and helps our domestic energy industry maintain worldwide technical leadership.



Source: Kuuskraa, V.A., "Undeveloped Domestic Oil Resources: The Foundation for Increasing Oil Production and a Viable Domestic Oil Industry," prepared for the U.S. Department of Energy, Office of Fossil Energy–Office of Oil and Natural Gas, Advanced Resources International (2006).

FIGURE 3-7. *Original, Developed, and Undeveloped Domestic Oil Resources*

The Conventional Wells Topic Report examines the current state of technology relating to conventional oil and natural gas wells, including enhanced oil recovery (EOR) and arctic resources, and makes projections on how technology could influence these businesses in the future (Figure 3-8).

The size and nature of the original, developed and undeveloped domestic oil resources are included in Table 3-4. Note that the domestic oil resources described in this report do not include oil shale. As points of comparison with this table, current proven crude-oil reserves are 22 billion barrels and annual domestic crude-oil production is about 2 billion barrels.

Of the 582 billion barrels of oil in place in discovered fields, 208 billion barrels already have been produced or proved, leaving behind 374 billion barrels. A significant portion of these 374 billion barrels is immobile or residual oil left behind (stranded) after application of conventional (primary and secondary) oil-recovery technology.[13] With appropriate EOR technologies, 110 billion barrels of this stranded resource from already discovered fields may become technically recoverable, although the conditions for economic recoverability will change over the study period to 2030.

Undiscovered domestic oil is estimated to be 360 billion barrels in place, with 119 billion barrels (43 billion barrels from onshore, 76 billon barrels from offshore) being recoverable with primary or secondary recovery. Application of advanced EOR could add another 60 billion barrels of technically recoverable resource from this category.

Future reserve growth in discovered oil fields could amount to 210 billion barrels of oil in place, with 71 billion barrels (60 billion barrels from onshore and 11 billion barrels from offshore) being recoverable with primary and secondary recovery. Application of advanced EOR could raise this technically recoverable volume by up to 40 billion barrels.

With advances in thermal EOR technology, domestic oil sands holding 80 billion barrels of resource in place could provide up to 10 billion barrels of future technically recoverable domestic oil resource.

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FIGURE 3-8. *Seismic Vessel in Iced-In Conditions*

The estimates of remaining, recoverable, domestic oil resources from undiscovered and reserve growth are from the national resource assessments by the United States Geological Survey (USGS) and the U.S. Minerals Management Service (MMS). The estimates of recoverable oil resources using EOR technology on stranded oil and oil sands are based on work by Advanced Resources International for DOE/Fossil Energy's Office of Oil and Natural Gas.

Since the preparation and publication of the Kuuskraa paper that provided a basis for this report, considerable additional work has been completed by the author's firm that further confirms the estimates of undeveloped U.S. oil resources. A total of 10 domestic oil basins and areas have now been assessed (up from the original 6). These 10 assessments indicate that the technically recoverable oil resource from application of "state-of-the-art" CO_2-EOR is 89 billion barrels. The earlier estimate of 80 billion barrels for applying EOR to the stranded light oil resource has been updated to 90 billion barrels (rounded off), as shown in Table 3-4.

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[13] Although the definitions vary, simply speaking, primary recovery comes from a reservoir's natural energy, while secondary recovery involves flooding with water or gas.

Crude Oil Resources*	Original Oil In Place	Developed to Date		Remaining Oil In Place	Future Recovery†		
		Conventional Technology	EOR Technology		Conventional Technology	EOR Technology‡	Total
Discovered	582	(194)	(14)	374	0	110	110
Light Oil	482	(187)	(2)	293	0	90	90
Heavy Oil	100	(7)	(12)	81	0	20	20
Undiscovered	360	0	0	360	119	60	179
Reserve Growth	210	0	0	210	71	40	111
Transition Zone	100	0	0	100	0	20	20
Tar Sands	80	0	0	80	0	10	10
Total	1,332	(194)	(14)	1,124	190	240	430

* Does not include oil shale.

† Technically recoverable resources rounded to the nearest 10 billion barrels.

‡ Based on ten basin-oriented assessments and residual oil zone resource potential highlighted in reports released by the Department of Energy Office of Fossil Energy in February 2006. V.A. Kuuskraa provided the updated EOR technology numbers for this table.

Sources: This table updates numbers from a table of U.S. oil resources recovery potential in a report from Advanced Resources International by V.A. Kuuskraa, "Undeveloped Domestic Oil Resources: The Foundation for Increasing Oil Production and a Viable Domestic Oil Industry," prepared for the U.S. Department of Energy's Office of Fossil Fuel in February 2006, and available at http://www.fossil.energy.gov/programs/oilgas/publications/eor_co2/Undeveloped_Oil_Document.pdf. The updated numbers are available from ARI at http://www.fossil.energy.gov/programs/oilgas/publications/eor_co2/G_-_Updated_U_S__Oil_Resources_Table_2-1.pdf. Note that the EIA estimates of remaining reserves are lower than those used here, see information in the NPC data warehouse and http://tonto.eia.doe.gov/dnav/pet/pet_crd_pres_dcu_NUS_a.htm.

TABLE 3-4. *Original, Developed, and Undeveloped Domestic Resources (Billions of Barrels)*

New work on the transition/residual oil zone resource documents the presence of 42 billion barrels of this category of oil in place in just three domestic oil basins (Permian, Big Horn, and Williston). Detailed reservoir simulation assessment shows that about 20 billion barrels of this oil in place could become technically recoverable by applying CO_2-EOR. This work provides support to the transition/residual oil zone resource estimate of 100 billion barrels in Table 3-4 and indicates that an important portion of this resource may become recoverable.

Finally, the author and his firm took an in-depth look at the additional oil recovery from applying "next-generation" CO_2-EOR technology. This work shows that combining: (1) advanced, high reservoir contact well designs; (2) mobility and miscibility enhancement; (3) large volumes of CO_2 injection; and (4) real-time performance feedback and process control technology could bring about "game changer" levels of improvement in oil recovery efficiency. This work provides support that a national average oil recovery efficiency target of 60 percent could become realistic, assuming a successful program of advanced technology development, affordable supplies of CO_2 and other EOR injectants, and appropriate risk-mitigation policies, such as federal and state tax incentives to help overcome the risk of applying these new technologies. The NPC studied EOR in 1976 and 1984, and raised great expectations for domestic EOR activity (projecting 3 million and 2 million barrels per day, respectively). These expectations have not been met. Peak domestic EOR

Technology	Time Frame	Discussion
Big increase in controlled reservoir contact	2015	Technologies allowing a continuing increase in the number of strategically placed horizontal wells will allow much greater commercial access to reserves.
Horizontal/ multilateral/ fishbone wells	2020	Multiple, placed drainholes from a main wellbore will further extend commercial access to reserves.
Arthroscopic well construction	2025	The ability to place drain holes to within feet of every hydrocarbon molecule in the formation allows the ultimate in recovery.
SWEEP (see, access, move)	2020	The combined technologies (including the four immediately below) allowing us to see, access, and move the hydrocarbons in the optimum way will bring a big increase to recoverable reserves.
Smart well (injection and production)	2015	The ability to control what fluids go where (at the wellbore).
Reservoir characterization and simulation	2015	Extending current technology to include simultaneous inversion of all measurements with a forward model.
Reservoir vision and management in real time	2020	Combining reservoir-scale measurements (pressure, seismic, electromagnetic, and gravity) in a joint inversion, with uncertainty and without data loss.
Mission control for everything	2030	Representation and control of the full system (subsurface and surface) allowing true optimization.
CO_2 flood mobility control	2020	Measurement and control of the CO_2 flood front is critical for successful implementation.
Steam-assisted gravity drainage (SAGD)/steam and alkaline-surfactant-polymer (ASP) technology	2020	Technologies to perfect and optimize SAGD operations (including the use of ASP) will be key to widespread economic exploitation of heavy oil.
Arctic subsea-to-beach technology	2030	Ice scouring of the seafloor surface presents a huge challenge to conventional approaches to subsea and subsea-to-beach operations.
Faster and more affordable, higher-definition, 3D seismic	2015	Quicker, better, cheaper could extend this already impressive specialized technology into universal use.

TABLE 3-5. *Summary of Highly Significant Technologies for Conventional Wells*

production occurred in 1992 at 761,000 barrels per day. Current activity is 680,000 barrels per day. In the interim, many technologies have been tried, but most failed. Two successes are CO_2-miscible floods and steam (cyclic, steam-assisted gravity drainage, and steam flood).

A broad portfolio of oil-recovery policies and technologies, plus targeted risk-mitigation incentives, would help industry convert these higher-cost, undeveloped domestic oil resources into economically feasible reserves and production. Table 3-5 lists the future technologies that study participants believed will provide the greatest impact on conventional wells, including EOR and arctic.

EXPLORATION TECHNOLOGY

Exploration technology has evolved significantly since 1859, when the first commercial oil well in the United States was drilled adjacent to an oil seep in Pennsylvania. Perhaps the most significant technological advance was the development of two-dimensional (2D) reflection seismology in the 1920s. The emergence of 2D seismic lines with improved processing led to the discovery of many of the world's largest oil and natural gas fields in the following decades. In the 1990s, three-dimensional (3D) seismic technologies became the industry standard, with improved resolution and characterization of the subsurface geology. Today, new ways of looking at seismic data focus on specific attributes and derivative properties that enhance identification of hydrocarbon prospects (e.g., direct hydrocarbon indicators) as well as computer tools that aid in quantitative interpretation of rock and fluid properties.

Improvements in exploration technology have had a significant impact on discovering resources, reducing finding costs, and improving exploration success rates both in the United States and globally.[14] Thanks to technological improvements, costs for 3D seismic acquisition and processing fell by almost a factor of 5 from 1990 to 2001 (Figure 3-9).[15, 16] Despite the substantial improvements in exploration technology and reduction in deployment costs since the 1970s, oil and gas explorers have not maintained the high discovery volumes of that earlier period. This decrease came despite the increased amount of 3D seismic surveys being shot over the period. Several authors concluded that improved exploration and exploitation technology has prevented a more drastic decline in discovery volumes.[17]

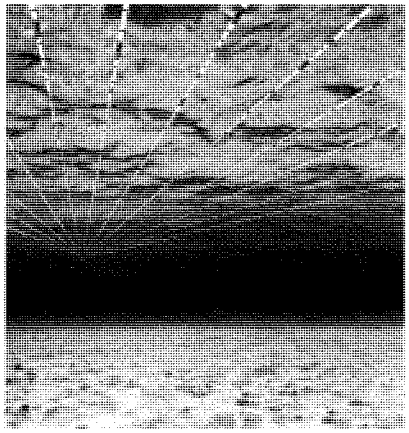
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FIGURE 3-9. *Graphic of Towed Seismic Streamers*

Some authors have suggested that improved methods of exploring for unconventional resources might reverse the trend; however, it should be noted that many unconventional resources have already been discovered and await new exploitation technologies.

The future of exploration technologies is bright, but it is still likely that the volumes of hydrocarbons discovered with time will continue to decrease, as shown historically in Figure 3-10, although the exploration success rate may continue to improve.[18] The Exploration Technology Topic Report identified five core exploration-technology areas in which future developments have the potential to significantly improve exploration results over the next 25 years:

- Seismic technology—High- and ultrahigh-density acquisition technologies have great potential for advances. Rapid data processing could significantly improve seismic resolution of complex subsalt, deep, or subtle geologic features.

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[14] Boutte, D, "The Role of Technology in Shaping the Future of the E&P Industry," *The Leading Edge* 23, no. 2 (2004): 156-158.

[15] Voola, J, "Technological Change and Industry Structure: A Case Study of the Petroleum Industry," *Economics of Innovation and New Technology* 15, no. 3 (2006): 271–288.

[16] Voola, JJR, Osaghae, O, and Khan, JA, "Risk Reducing Technology and Quantity Competition: The Seismic Story," paper SPE 88583 presented at the SPE Asia Pacific Oil and Gas Conference and Exhibition, Perth, Australia (October 18–20, 2004).

[17] Cuddington, JT and Moss, DL, "Technological Change, Depletion and the U.S. Petroleum Industry: A New Approach to Measurement and Estimation," Georgetown University Working Paper #96-10R (1998).

[18] Bahorich, M, "End of Oil? No, It's a New Day Dawning," *Oil & Gas Journal* (August 21, 2006): 30–34.

- Controlled source electromagnetism (CSEM)—CSEM identifies subsurface hydrocarbon accumulations through a contrast in resistivity between hydrocarbon-saturated and water-saturated reservoirs. Two key potential improvements are:
  - Development of fast 3D modeling and inversion to reduce the number of erroneously identified "anomalies" (false positives)[19]
  - Extension of the technology to shallow-water and onshore settings.
- Interpretation technology—Interpreters struggle with the sheer volume and complexity of data and the need for increasingly quantitative interpretations. Two advances that could have significant results are:
  - Better integration of geophysical and geologic data to develop quantitative interpretations
  - Development of seismic search engines to interrogate increasing data volumes.[20]
- Earth-systems modeling—Modeling natural systems of basin formation, fill, and fluid migration is becoming increasingly common. Advances in modeling more-integrated earth systems along with capturing uncertainties in potential scenarios and parameters could significantly help explorationists to identify new plays (areas for exploration) and "sweet spots" (localized exploration targets).
- Subsurface measurements—Measurement of subsurface properties (fluid type, porosity, permeability, temperature, etc.) is crucial to exploration success. Advances in sensor types, durability, sensitivity, and deployment could improve exploration programs significantly by identifying both penetrated and bypassed "pay," that is, economically producible hydrocarbons that may or may not have been intercepted by a wellbore.

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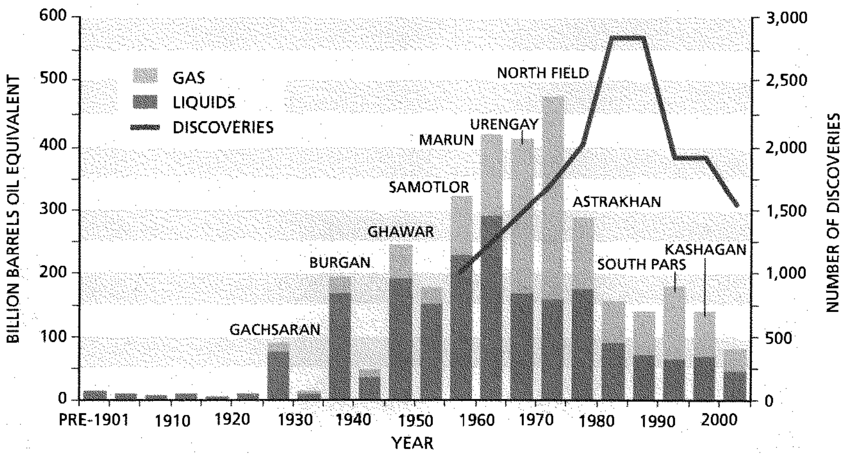
[19] Inversion is a mathematical process by which data are used to generate a model that is consistent with the data. See www.glossary.oilfield.slb.com/Display.cfm?Term=inversion.

[20] Barnes, A, "Seismic Attributes in Your Facies," *CSEG Recorder* (September 2001): 41-47.



Source: IHS Energy (Bahorich, 2006).

***FIGURE 3-10.** Evolution of Oil Discovery Volumes with Time*
(Total Discovered Resources to End-2004, excluding United States and Canada)

This Exploration Technology Subgroup highlighted unconventional resources as a special category in the early stages of understanding (both exploration and exploitation) to which many of the core exploration technologies could potentially be applied. Two key advances could improve the effectiveness of exploration for unconventional resources:

- Improved measurement capabilities and predictive modeling of the geologic factors controlling hydrocarbon distribution and deliverability.
- Significant improvements in exploration or exploitation technologies that could help define exploration targets ("sweet spots") and the technologies needed to identify them.

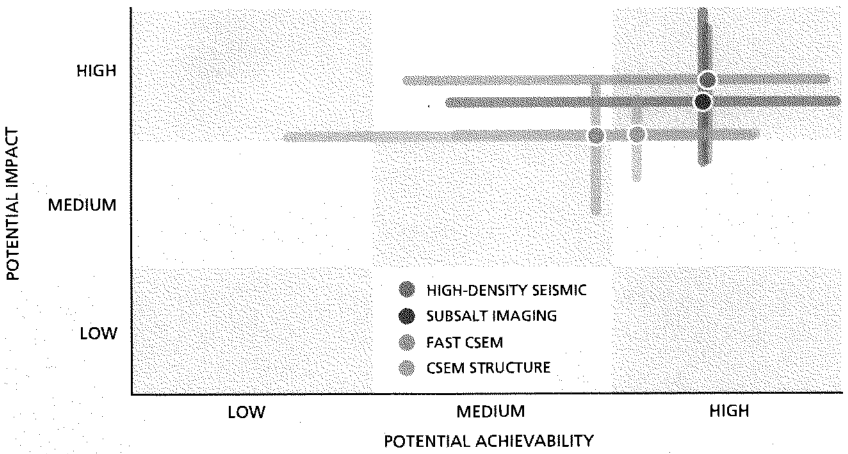
The Exploration Technology Topic Report also identified auxiliary technologies in which future developments or applications have the potential to significantly improve exploration results by 2030:

- Drilling technology—Projected technical advances could improve the ability to tap new environments and encourage more exploration drilling of higher risk, new play types via reduced drilling costs.
- Nanotechnology—The most likely opportunities for applications are in increased sensor sensitivity, improved drilling materials, and faster and more powerful computing.
- Computational technology—Improvements in speed, memory, and cost will impact data acquisition, processing, and interpretation industry-wide.

Research into technologies that could mitigate potential environmental impacts will continue to

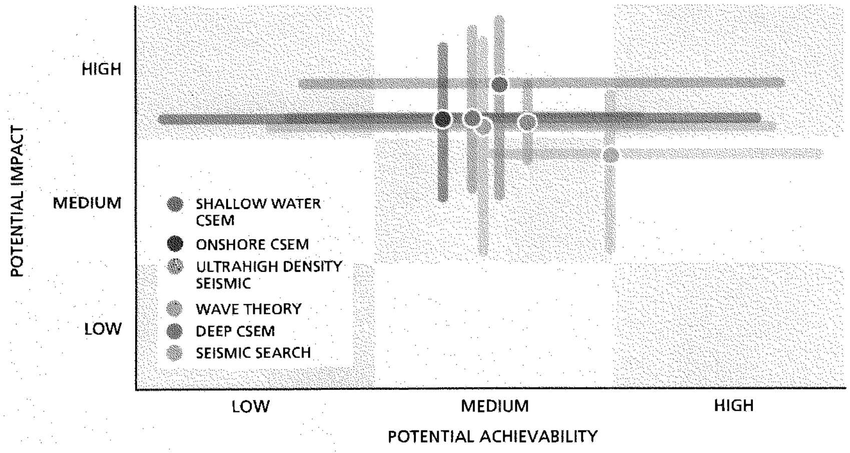
Technology	Significance	Brief Discussion
High-density seismic data and rapid data processing	High	Higher-density seismic data acquisition with greater signal-to-noise ratios result in greater resolution, which allows for more robust interpretations of reservoir character and hydrocarbon potential to be made. However, for higher-density data to have commercial impact, substantial improvements in processing methods must be made.
Subsalt imaging (seismic)	High	Salt is a highly distorting acoustic lens that creates "blind spots" beneath it. Considerable efforts have been made to produce high-quality subsalt images resulting in drilling success in the Gulf of Mexico. Enhanced subsalt imaging will undoubtedly result in new discoveries and improved economics.
Fast controlled source electromagnetism (CSEM) 3D modeling and inversion	High	CSEM can discriminate between scenarios that are indistinguishable via seismic amplitudes; e.g., commercial oil versus residual (non-commercial) natural gas. However, false positives are common; e.g., hydrates, salts, and volcanics can yield a response similar to a commercial petroleum response. Fast 3D modeling and inversion capability can help discriminate against such false positives.
Integration of CSEM with structural information from seismic surveys	High	An important approach to increase the resolution of information obtained via CSEM methods.

TABLE 3-6. *Summary of Highly Significant Nearer-Term (by 2010) Exploration Technologies*



Note: CSEM = controlled source electromagnetism.

FIGURE 3-11. *Potential Impact versus Achievability for Nearer-Term Exploration Technology Advances*



Note: CSEM = controlled source electromagnetism.

FIGURE 3-12. *Potential Impact versus Achievability for Longer-Term Exploration Technology Advances*

Technology	Significance	Brief Discussion
Shallow-water controlled source electromagnetism (CSEM)	High	The shallow-water environment is much noisier than the deepwater environment for CSEM techniques. Substantial advances are needed to enable robust signal acquisition and analysis in such an environment. But, if successful, it can open up the application domain for CSEM beyond deepwater basins.
Onshore CSEM	High	The onshore environment is much noisier than the deepwater environment for electromagnetic techniques. Substantial advances are needed to enable robust signal acquisition and analysis in such an environment. But, if successful, it can open up the application domain for CSEM beyond deepwater basins.
Ultra high-density data and processing	High to medium	Data density and processing continue to improve at incremental steps. However, if extremely high-density data could be acquired and processed rapidly at low costs, game-changing breakthroughs could occur. These include new hydrocarbon discoveries as well as exploitation efficiencies.
Wave theory research (seismic)	Potential high impact but with attendant high risk	Basic research into wave theory is a continuing effort in both industry and academia. Synergistic collaborations between the two have led to gradual improvements in processing and could result in large leaps forward. For example, it should enable more accurate quantitative modeling of key seismic data.
Deep CSEM	High to medium	Even in deep water, current application is limited to relatively shallow reservoirs (6,500 to 10,000 feet below sea floor). Advances in penetration depth could open up applications in several new basins.
Development of an automated "seismic search engine" to find new opportunities	Medium to high	This type of technology would take advantage of advances in computational power, pattern recognition technology, geophysical data, and geological concepts in a highly automated fashion.

TABLE 3-7. *Summary of Highly Significant Longer-Term Exploration Technologies*

be important. Examples of active areas of research include:

- Mud recovery without a riser from seabed to surface, which reduces discharge
- Ultra-extended-reach drilling, which can help avoid sensitive surface environments
- Research into seismic sources that are alternatives to the conventional seismic airgun arrays.

Complementary research efforts on marine biology and other topics could provide better data to improve informed-risk assessment, public debate, and informed decision-making by regulatory agencies.

Significant nearer-term technologies are outlined in Table 3-6 and Figure 3-11, with longer-term technologies described in Table 3-7 and Figure 3-12.

DEEPWATER TECHNOLOGY ◆

Deepwater oil and natural gas resources are conventional reserves in an unconventional setting. They constitute a resource class of their own, largely because they face a common set of technological challenges as they are identified, developed, and produced (Figure 3-13).

The U.S. Gulf of Mexico represents a clear case where the more we know, the more attractive the opportunities for oil exploration and discovery become. Figure 3-14 illustrates that our appreciation for the scope of the potential total Gulf of Mexico resource has grown dramatically as deepwater production has come online.[21]

Deepwater exploration is a success for both technology and policy that is still in the making. The data continue to support significant scope for economic oil and natural gas resource development in both U.S. and global deep oceans. Ahead lie four top-priority, deepwater-specific technological challenges:

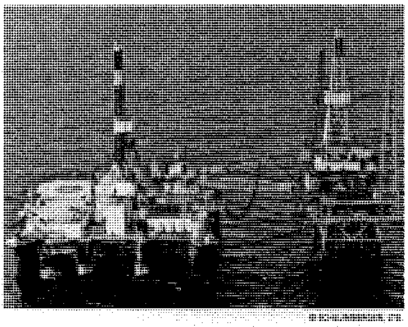
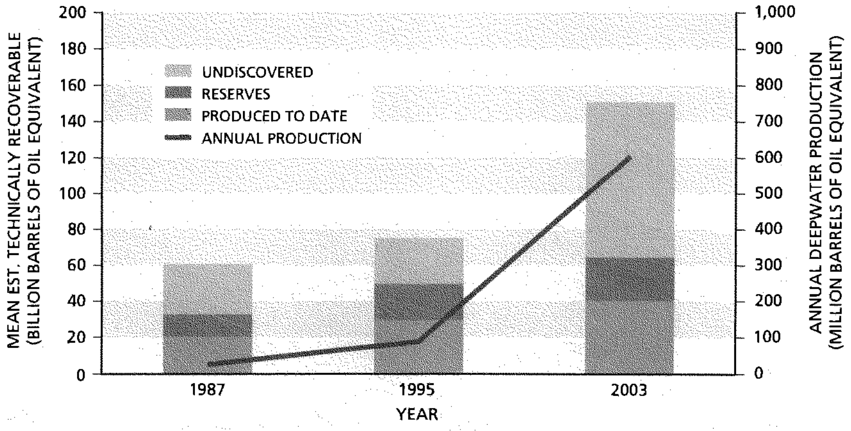


FIGURE 3-13. *Offshore Platforms*

1. Reservoir characterization: predicting and monitoring the production behavior of increasingly complex reservoirs with fewer—but more costly—direct well penetrations.



Source: Report to Congress: Comprehensive Inventory of U.S. OCS Oil and Natural Gas Resources, Energy Policy Act of 2005 – Section 357.

FIGURE 3-14. *U.S. Gulf of Mexico Oil and Natural Gas Resource Endowment*

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[21] Report to Congress: Comprehensive Inventory of U.S. OCS Oil and Natural Gas Resources, Energy Policy Act of 2005 – Section 357. Available at www.mms.gov/revaldiv/PDFs/FinalInvRptToCongress050106.pdf.

2. Extended system architecture: subsea systems for flow assurance (the ability to produce and move fluids to surface), well control, power distribution and data communications that improve recovery and extend the reach of production hubs to remote resources.

3. High-pressure and high-temperature (HPHT) completion systems: materials and equipment to reliably produce the growing number of deepwater resources in corrosive environments with extraordinary pressures and temperatures.

4. Metocean (combined meteorological and oceanic) forecasting and systems analysis: integrated models to predict both atmospheric and below surface "weather" and engineering system response.

Within these four priority areas, HPHT completion systems and metocean forecasting and systems analysis represent opportunities for practical government and industry cooperation. Accelerating progress in HPHT service is likely to cost hundreds of millions of dollars over many years. Excellent potential exists to transfer or co-develop fundamental materials science and engineering technologies across industry boundaries—most notably aerospace and military (especially naval). Thus, although these are domains of intentional industry pursuit, there is compelling scope for collaborative research in academia and government labs. Theoretical developments for both the weather and engineering systems could be accelerated with a few millions of dollars. Development and operation of regional data-acquisition technologies and associated predictive capabilities will likely cost tens to hundreds of millions of dollars.

Additionally, it is important to understand that deepwater technology is tightly related to topics covered by other NPC Technology Topic Papers (Table 3-8). We have also identified two issues that we conclude are critical to the continued successful development of oil and natural gas resources in ever-harsher ocean environments (Table 3-9).

Marine sciences and engineering is a specialty field in which many disciplines (e.g., mechanical and civil engineering) can be taught to apply known techniques. However, the few small centers of excellence that have historically trained the leading marine thinkers, conceptualizers, and innovators are disappearing due to university competition for research in information-, nano-, and bio-technologies—MIT, Michigan, and Berkeley, for example. The U.S. Navy has also recognized this nationally important concern. Improving the current situation is likely to cost tens of millions of dollars for top-tier universities in ocean sciences and marine engineering.

A second key issue, policies about access to acreage for the purposes of oil and natural gas exploration and development, raises complex matters. However, access to acreage with potential for economic oil and natural gas resources is itself a major—perhaps primary—driver encouraging technology development. For example, the onset of area-wide leasing for the U.S. Gulf of Mexico in the early 1980s led to significant acceleration of interest in deepwater regions.

Technology	Significance	Brief Discussion
Subsalt imaging (Exploration technology topic)	Finding large new resources	Novel seismic processing methods that enable one to accurately image below complex salt layers
Gas liquefaction (Supply topic)	Bringing remote natural gas to market	Technology to convert natural gas into more easily transportable forms becomes more valuable with both distance from shore and water depth
Arctic (Conventional well technology topic)	Large untapped offshore regions	Economic development of oil and natural gas in the offshore arctic will likely build on traditional deepwater technologies

TABLE 3-8. *Summary of Technologies Related to Deepwater Technology, in Priority Order*

Technology	Significance	Brief Discussion
Future marine technology leadership	Innovation capability	Reduced centers of excellence in specialized field of marine science and engineering will limit inflow of technical experts required to keep industry moving forward after the "big crew change."
Valuing technology to enable access	Innovation motivation	Access to acreage with potential for economic oil and natural gas resources is in and of itself a primary, if not the largest, driver that encourages technology development.

TABLE 3-9. *Summary of Key Deepwater Issues, in Priority Order*

The coming decade will be pivotal for determining our ability to safely and economically develop the energy resource endowment in U.S. and global oceans. At the very time the drive to ultra-deep waters is increasing both the magnitude and complexity of the challenge, the technological capacity of the workforce faces untimely impairment by "the big crew change." The future of deepwater exploration and production depends on industry and governments successfully co-navigating this linked technology and policy transition.

UNCONVENTIONAL NATURAL GAS RESERVOIRS—TIGHT GAS, COAL SEAMS, AND SHALES

Unconventional natural gas resources—including tight sands, coalbed methane, and gas shales—constitute some of the largest components of remaining natural gas resources in the United States. Unconventional natural gas is the term commonly used to refer to low-permeability reservoirs that produce mainly natural gas with little or no associated hydrocarbon liquids. Many of the low-permeability reservoirs that have been developed in the past are sandstone, but significant quantities of gas are also produced from low-permeability carbonates, shales, and coal seams. One way to define unconventional natural gas is that "the reservoir cannot be produced at economic flow rates nor recover economic volumes of natural gas unless the well is stimulated by a large hydraulic fracture treatment, a horizontal wellbore, or by using multilateral wellbores."[22]

Research and development on the geologic controls and production technologies required to evaluate and produce these unconventional natural gas resources have provided many new technologies during the past several decades. New technologies have enabled operators in the United States to unlock the vast potential of these challenging resources, boosting production levels to about 30 percent of current U.S. natural gas production (Figure 3-15).

Around the world, unconventional natural gas resources are widespread but, with several exceptions,

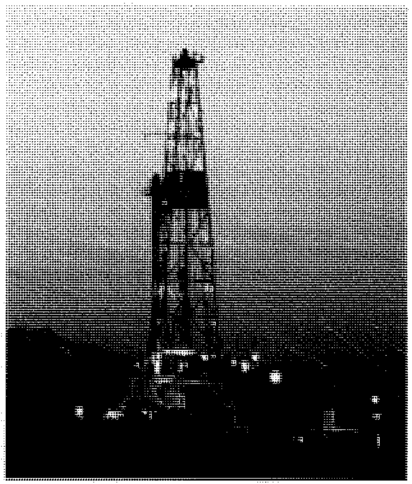

FIGURE 3-15. *Land Drilling Rig*

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[22] Holditch, SA, "Tight Gas Sands," SPE Paper 103356, Distinguished Author Series (2006).

they have not received close attention from natural gas operators. This is due, in part, because geologic and engineering information on unconventional resources is scarce, and natural gas policies and market conditions have been unfavorable for development in many countries. In addition, there is a chronic shortage of expertise in the specific technologies needed to successfully develop these resources. As a result, only limited development has taken place to date outside North America. Interest is growing, however, and during the last decade development of unconventional natural gas reservoirs has occurred in Canada, Australia, Mexico, Venezuela, Argentina, Indonesia, China, Russia, Egypt, and Saudi Arabia.

Many of those who have estimated the volumes of natural gas in place within unconventional gas reservoirs agree that it is a large resource (Table 3-10). Using the United States as an analogy, there is good reason to expect that unconventional gas reservoir production will increase significantly around the world in the coming decades.

Tight Gas Sands

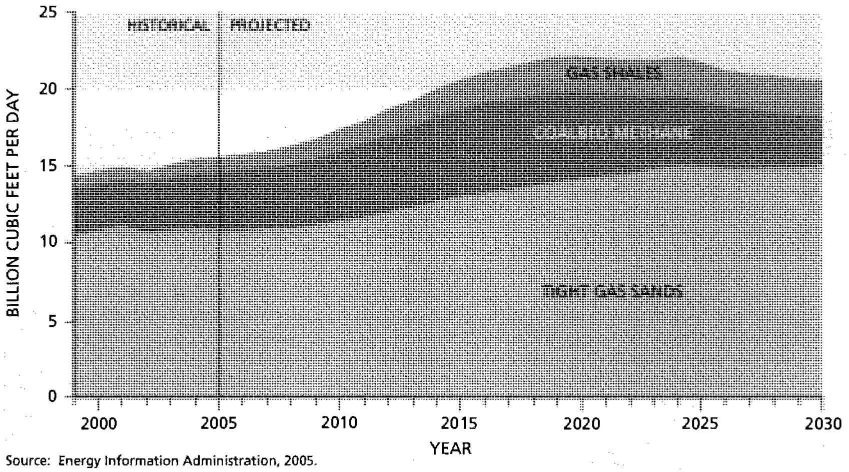
From a global perspective, tight gas resources can be considered vast, but undefined. No systematic evaluation has been carried out on global emerging resources. The magnitude and distribution of worldwide resources of natural gas in tight sands, as well as gas shales and coalbed methane formations, have yet to be understood.

From almost no production in the early 1970s, today unconventional resources, particularly tight sands, provide almost 30 percent of domestic natural gas supply in the United States. The volumes of natural gas produced from U.S. unconventional resources are projected to increase in importance over the next 25 years, reaching production levels as high as 22 billion cubic feet per day (Figure 3-16).

Region	Coalbed Methane	Shale Gas	Gas in Tight Sands	Total
North America	3,017	3,840	1,371	8,228
Latin America	39	2,116	1,293	3,448
Western Europe	157	509	353	1,019
Central and Eastern Europe	118	39	78	235
Former Soviet Union	3,957	627	901	5,485
Middle East and North Africa	0	2,547	823	3,370
Sub-Saharan Africa	39	274	784	1,097
Centrally Planned Asia and China	1,215	3,526	353	5,094
Pacific	470	2,312	705	3,487
Other Asia Pacific	0	313	549	862
South Asia	39	0	196	235
World	9,051	16,103	7,406	32,560

Source: Kawata and Fujita, "Some Predictions of Possible Unconventional Hydrocarbons Availability Until 2100," Society of Petroleum Engineers, SPE Paper 68755, 2001.

__TABLE 3-10.__ Distribution of Worldwide Unconventional Natural Gas Resources (Trillion Cubic Feet)



Source: Energy Information Administration, 2005.

FIGURE 3-16. *U.S. Unconventional Natural Gas Production and Future Projection*

Coal Seams

Coalbed methane (CBM) perhaps best exemplifies how technology can influence the understanding and eventual development of a natural gas resource. While natural gas has been known to exist in coal seams since the beginning of the coal-mining industry, only since 1989 has significant production been realized (Figure 3-17).

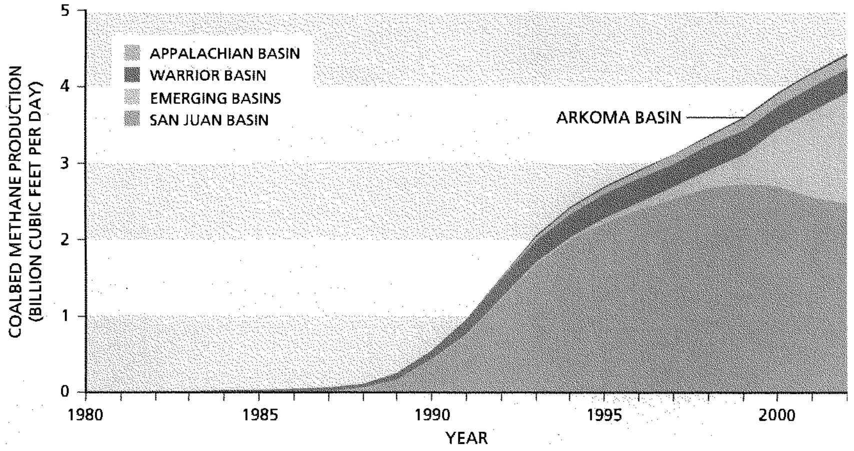
CBM is a resource that was drilled through and observed for many years, yet never produced. New technology and focused CBM research ultimately unlocked the production potential. CBM now provides more than 4.4 billion cubic feet of natural gas production a day in the United States, and is under development worldwide, including the countries of Canada, Australia, India, and China.

In many respects, the factors controlling CBM production behavior are similar to those for conventional natural gas resources, yet they differ considerably in other important ways. One prominent difference is the understanding of the resource, especially the values of gas in place. Natural gas in coal seams adsorbs to the coal surface, allowing for significantly more to be stored than in conventional rocks amid shallow, low-pressure formations. To release the adsorbed gas for production, operators must substantially reduce the pressure in the reservoir. Adsorbed gas volumes are not important for conventional gas resources, but are critical for CBM reservoirs. Significant research was required in the 1990s to fully understand how to produce the adsorbed gas in coal seams, and to develop the technology required to explore for—and produce—CBM reservoirs.

A major difference between CBM reservoirs and sandstone gas reservoirs is that many of the coal seams are initially saturated with water. Thus, large volumes of water must be pumped out of the coal seams before realizing any significant gas production. This water production reduces the pressure so desorption will occur. The technology developed in the 1990s for understanding and dewatering coal seams allowed significant CBM development in several U.S. geologic basins.

Shale Gas

Shale rocks act as both the source of the natural gas and the reservoir that contains it. Natural gas is stored



Source: IHS Energy.

FIGURE 3-17. *Natural Gas Production from Coal Seams in the United States*

in the shale in three forms: free gas in rock pores, free gas in natural fractures, and adsorbed gas on organic matter and mineral surfaces. These different storage mechanisms affect the speed and efficiency of gas production.

Shale gas production in the United States has shown that stimulation techniques, especially hydraulic fracturing, are almost always necessary for shale gas production. Other important technology advances include applying horizontal and directional drilling, and characterizing reservoirs. For wells in the Barnett Shale (near Fort Worth, Texas), using technology currently available, the per-well recovery factor averages 7 percent of the gas in place. This is far below a potentially achievable 20 percent recovery factor.

In areas with limited surface access and landowner restrictions, horizontal drilling has been applied. Horizontal wells provide greater wellbore contact within the reservoir rocks than do vertical wells. Microseismic fracture mapping has also been successfully used to improve the evaluation of hydraulic fracturing in the horizontal wells.

Tables of Advances

Tables 3-11, 3-12, and 3-13 describe current technology under development and that which needs to be developed and used in future years. These tables indicate only the high-impact technologies; others are described in the Unconventional Gas Topic Paper. The priority was determined by estimating the difference in impact between a business-as-usual case and an accelerated-technology case. High impact includes those technologies having greatest possibilities for producing more gas or reducing cost, while for moderate impact effectiveness is lesser or is more difficult to measure.

The amount of research and development needed to fully develop a given technology is described in these tables as follows:

- Incremental—research and development as usual
- Accelerated—research and development as usual, but with a major increase in funding (factors of 3 to 5)
- Breakthrough—substantial increase in funding (factors of 10 to 100) and more use of consortiums.

Unconventional Gas Technology Under Development or Anticipated by 2010	Research and Development Required for Success	Discussion
Fracture modeling and analysis, full 3D models for new types of treatments	Accelerated	Incorporating new physics for fracture propagation, in naturally fractured reservoirs, fracture-proppant transport, and better models for horizontal and multilateral wells.
New fracturing fluids and proppants	Incremental	Strong, light-weight proppants are needed. Better fluids that do not damage the reservoir and fracture must be developed.
Hydraulic fracturing methods used in horizontal wells	Incremental	Fort Worth basin (Barnett Shale): Increased production rate by 2 to 3 times rate of vertical well.
Stimulation methods used in naturally fractured formations	Incremental	Gas shales and coal seam reservoirs are normally naturally fractured. We need a better understanding and better technologies for such reservoirs to include better models to determine gas storage and gas production using multiple gas systems, such as CO_2, wet gas, and N_2.
Micro-seismic fracture mapping and post-fracture diagnostics	Accelerated	Fort Worth basin (Barnett Shale): improved understanding of hydraulic fracturing in horizontal wells so that designs can be improved.
Data collection and availability during drilling, completions, stimulations, and production	Incremental	Significant data are being generated by increased drilling and new tools and techniques. The ability to handle and use data is being challenged. The data need to be evaluated in detail to learn more about formation evaluation, fracture treatments and production.
Integrated reservoir characterization of geologic, seismic, petrophysical, and engineering data	Accelerated	More complex reservoirs, lower permeability, greater depth and more cost require a more in-depth understanding of reservoir petrophysics. Better models will be required to properly integrate all the data and optimize the drilling and completion methods.
Horizontal drilling and multilateral wellbore capability	Accelerated	Enables development of stacked, thin-bed coal seams and reduces environmental impact. Also need to develop multiple wells from a single pad. This technology is very important in shale-gas reservoirs, and sometimes important in tight-gas reservoirs.
Reservoir characterization through laboratory measurements	Accelerated	We need better core-analysis measurements for basic parameters such as permeability, porosity, and water saturation. In coal seams and shales, we need better methods for estimating sorbed gas volumes and gas-in-place values in the reservoir.
Reservoir imaging tools	Incremental	Understanding the reservoir characteristics is an ongoing challenge and priority for all unconventional reservoirs.
Overall environmental technology	Accelerated	We need to reduce the impact of operations on the environment by reducing waste, reducing noise, using smaller drilling pads and adequate handling of waste water.
Produced water handling, processing and disposal	Accelerated	Coal seams and shale gas continue to produce significant volumes of water. Efficient handling and environmentally safe and low impact disposal are needed.

TABLE 3-11. *Summary of Currently Developing Technologies for Unconventional Natural Gas from Now to 2010 (Those with High Significance Only)*

2020 Technology for Unconventional Gas Reservoirs	Research and Development Required for Success	Discussion
Real-time sweet-spot detection while drilling	Breakthrough	Will allow the steering of the drill bit to the most productive areas of the reservoir.
Coiled tubing drilling for wells less than 5,000 ft.	Accelerated	Will allow the advantages of continuous tubing drilling to be realized (fast drilling, small footprint, and rapid rig moves) for currently difficult drilling areas.
3D seismic applications for imaging layers and natural fractures in shale reservoirs	Accelerated	We could improve recovery efficiency from existing wells if we used well testing methods to better understand the reservoirs.
Produced-water processing	Accelerated	Produced water is processed and utilized such that it no longer is viewed as a waste stream but as a valuable product for agriculture, industrial use, and for all well drilling and completion needs.
Deep drilling	Incremental	We need to determine how deep we can develop coalbed methane, shale gas and other naturally fractured unconventional reservoirs.
Enhanced coalbed methane production via CO_2 injection/ sequestration	Accelerated	We need to determine the technological solutions and screening of suitable pairing of deposits and CO_2 sources.
Data handling and databases	Incremental	Databases are available and user-friendly allowing access to geologic and engineering data for most North American basins, and are being developed for geologic basins worldwide.

TABLE 3-12. *Summary of Technologies Anticipated for 2020 (Those with High Significance Only)*

2030 Technology for Unconventional Gas Reservoirs	Research and Development Required for Success	Discussion
Resource characterization and gas-in-place potential	Accelerated	All of the basins worldwide need to be assessed for unconventional gas potential. The results should be recorded in databases and made available to the producing community around the world.
Well drilling and completion	Accelerated	Well drilling technology must be advanced through improvement in downhole drilling systems, better metallurgy and real time downhole sensors allowing drilling to sweet spots, use of underbalanced drilling where needed, advantages of continuous tubing drilling, and efficient utilization of multilaterals.

TABLE 3-13. *Summary of Technologies Anticipated for 2030 (Those with High Significance Only)*

UNCONVENTIONAL HYDROCARBONS: HEAVY OIL, EXTRA-HEAVY OIL, AND BITUMEN ✦

Heavy oil, extra-heavy oil, and bitumen are unconventional oil resources that are characterized by high viscosity (resistance to flow) and high density compared to conventional oil. Most heavy oil and bitumen deposits originated as conventional oil that formed in deep formations, but migrated almost to the surface where they were degraded by bacteria and by weathering, and where the lightest hydrocarbons escaped (Figure 3-18). Heavy oil and bitumen are deficient in hydrogen and have high carbon, sulfur, and heavy metal content. Hence, they require additional processing (upgrading) to become a suitable feedstock for a normal refinery.

The IEA estimates that there are 6 trillion barrels of heavy oil worldwide, with 2 trillion barrels ultimately recoverable.[23] Western Canada is estimated to hold 2.5 trillion barrels, with current reserves of 175 billion barrels. Venezuela is estimated to hold 1.5 trillion barrels, with current reserves of 270 billion barrels. Russia may also have more than 1 trillion barrels of heavy oil. Heavy-oil resources in the United States amount to 100 to 180 billion barrels of oil, with large resources in Alaska (44 billion barrels), California (47 billion barrels), Utah (19 to 32 billion barrels), Alabama (6 billion barrels), and Texas (5 billion barrels). Heavy oil has been produced in California for 100 years, and currently amounts to 500,000 barrels per day of oil. Heavy oil resources in Alaska are being developed on a small scale with less than 23,000 barrels per day of oil in 2003.[24] Heavy oil and bitumen resources in Western Canada and the United States could provide long-term, stable, and secure sources of oil for the United States. Most of these resources are currently untapped.

Heavy oil is also located—and being produced—in Indonesia, China, Mexico, Brazil, Trinidad, Argentina, Ecuador, Colombia, Oman, Kuwait, Egypt, Saudi Arabia, Turkey, Australia, India, Nigeria, Angola, Eastern Europe, the North Sea, Iran, and Italy.

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FIGURE 3-18. *High-Viscosity Heavy Oil Acquired by Wireline Sampling*

Exploration technology has minor significance since large resources have already been discovered, but optimizing production technology is important. Because heavy oil, extra-heavy oil, and bitumen do not flow readily in most reservoirs, they require specialized production methods. Very shallow oil sands can be mined. Slightly deeper deposits can be produced by increasing reservoir contact with horizontal wells and multilaterals (multiply branched wellbores), producing the oil with large amounts of sand, or by injecting steam, which lowers the viscosity and reduces the residual oil saturation, thus improving recovery efficiency (Figure 3-19). In situ combustion has also been used to heat the reservoir, but several technical and economic challenges limit application of this technique. A few reservoirs are sufficiently hot that heavy oil can be produced using essentially conventional methods.

The production of heavy oil, extra-heavy oil, and bitumen is economic at current oil prices with existing production technologies. However, heavy oil and bitumen sell at a lower price than conventional oil because it is more difficult to process the heavier crude to create refined products, and because fewer refineries have the capability to process it. In addition, production is more costly than for conventional oil, so the profit margin is less. If an oil company has equal access to conventional oil and to heavy oil,

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[23] Christian Besson, *Resources to Reserves, Oil & Gas Technologies for the Future*, International Energy Agency (2005), p. 75.

[24] *Undeveloped Domestic Oil Resources: The Foundation for Increasing Oil Production and a Viable Domestic Oil Industry*, Advanced Resources International, Feb. 2006, p. 12, 18.

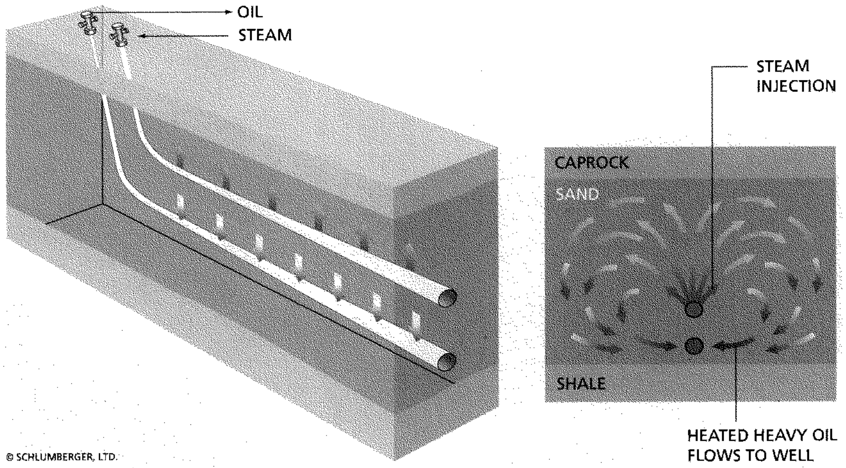

FIGURE 3-19. *Steam-Assisted Gravity Drainage Process for Producing Heavy Oil*

economics would favor conventional oil. However, gaining access to conventional oil resources is becoming more difficult in many countries.

There are several barriers to the rapid growth of heavy oil, extra-heavy oil, and bitumen production. Open-pit mining has a large environmental

Method	Locations used	Factors
Open pit mining	Canada, for shallow oil sands	High recovery factor, but high environmental impact
Cold production using horizontal wells and multilateral wells	Venezuela and some use in North Sea	Low recovery factor, may use water drive (North Sea)
Cold heavy oil production with sand (CHOPS)	Western Canada, to exploit thin layers	Low recovery factor, needs good gas/oil ratio, unconsolidated sands
Cyclic steam stimulation (CSS)	United States, Canada, Indonesia, many others	Reduce viscosity of heavy oil, needs good caprock, fair to good recovery factor
Steam flood	United States, Canada, Indonesia, many others	Follow-up to CSS for inter-well oil, good to high recovery factor
Steam-assisted gravity drainage (SAGD)	Canada	Allows production from shallower sands with weaker caprock

TABLE 3-14. *Major Commercial Production Methods for Heavy Oils*

Method	Time Frame	Description	Advantage
Vapex	2010	Use solvent rather than steam in SAGD-type wells	Lower energy consumption, low production rates
Hybrid	2010	Solvent plus steam in SAGD, CSS, and steam-flood wells	Lower energy consumption, increased production
In situ combustion with vertical and horizontal wells	2010	Uses heavy oil in reservoir and injected air	Eliminate need for natural gas for steam generation
Downhole heating with electricity	2010	Resistance, induction, or radio-frequency	Offshore, deep and arctic regions
Alternative fuels with gasification and carbon capture and sequestration	2020/ 2030	Uses coal, coke, or heavy ends for energy and hydrogen	CO_2 reduction in a CO_2 limited world
Nuclear power plant fit-for-purpose	2020/ 2030	Small scale for energy and hydrogen production	CO_2 reduction in a CO_2 limited world, safety, proliferation, fuel disposal, societal concerns
In situ upgrading	2020/ 2030	Application of in-situ thermal energy with or without catalysts to upgrade oil in place	Critical energy balance
Downhole steam generation	2020/ 2030	Possible options include generating heat downhole from either electricity or combustion of fuel.	Arctic, offshore, deep formations
Combination subsurface mining and well production techniques	2020/ 2030		Arctic and extremely restricted surface footprint environments

TABLE 3-15. *Major Heavy-Oil Production Methods, with Time Frame for Commercialization*

impact and can only exploit resources near the surface; further, it is a mature technology and only evolutionary improvements in efficiency are likely. By contrast, there are several commercial in situ production technologies, and several more are in research or the pilot phase. Many of the in situ production methods require an external energy source to heat the heavy oil to reduce its viscosity. Natural gas is currently the predominant fuel used to generate steam, but it is becoming more expensive due to tight supplies in North America. Alternative fuels such as coal, heavy oil, or byproducts of heavy-oil upgrading could be used, but simply burning them will release large quantities of CO_2. One option is gasification with carbon capture and sequestration. Nuclear power has also been proposed as a heat source, bnt faces societal opposition. Another fuel option is using the unconventional oil itself by injecting air into the reservoir for in situ combustion.

Other in situ methods are undergoing pilot testing. Vapex uses a solvent to reduce heavy-oil viscosity by itself or in combination with steam. These could reduce energy requirements and possibly open resources that are too deep, in arctic regions, or offshore where steam injection is difficult. Other options are generating steam downhole, or directly heating the formation by electricity—such as resistance, induction, or radio-frequency heating. Research indicates that some in situ upgrading may also be possible with heat, combustion, solvents, or catalysts.

Heavy oil, extra-heavy oil, and bitumen projects are large, capital-intensive undertakings. This capital spending includes the production infrastructure and additional upgrading, refining, and transportation facilities, plus pipelines for heavy oil and possibly for CO_2 sequestration. Another issue is obtaining a sufficient supply of diluent for moving heavy oil by pipeline. These projects also have long operating and payback periods, so unstable oil prices can deter long-term investments. Skilled people are also required to staff these projects.

Technologies that upgrade value, drive down costs, and reduce environmental effects will have the greatest influence on increasing the production of heavy oil, extra-heavy oil, and bitumen. There are a large number of technologies that can achieve these goals, but there is no single, simple solution owing to the tremendous variety of heavy oil, extra-heavy oil, and bitumen resources.

A list of commercial production methods is shown in Table 3-14, and a list of pre-commercial production methods is in Table 3-15.

UNCONVENTIONAL HYDROCARBONS: OIL SHALE ◆

Oil shale comprises a host rock and kerogen. Kerogen is organic matter that has not gone through the "oil window" of elevated temperature and pressure necessary to generate conventional light crude oil. Kerogen has a high hydrogen/carbon ratio, giving it the potential to be superior to heavy oil or coal as a source of liquid fuel (Figure 3-20). Globally, it is estimated that there are roughly 3 trillion barrels of shale oil in place, which is comparable to the original world endowment of conventional oil. About half of this immense total is to be found near the common borders of Wyoming, Utah, and Colorado, where much of the resource occurs at a saturation of more than 25 gallons of product per ton of ore (about 10 percent by weight) in beds that are 100 to 1,000 feet thick. Like heavy oil reservoirs, oil shale is found near the surface, ranging from outcrops down to about 3,300 feet.

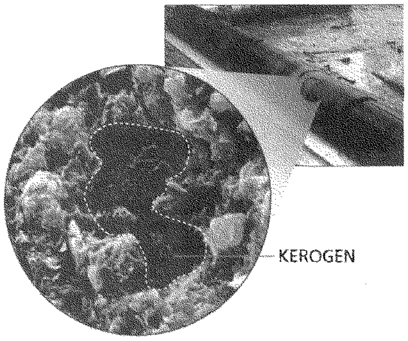

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FIGURE 3-20. *Shale Core, with Scanning Electron Micrograph indicating Kerogen Content*

In the past, the most common production technology has been surface mining in conjunction with processing in above-ground retorts. With process temperatures at about 930°F, these techniques convert kerogen to oil in about an hour. This approach has the virtue of simplicity, but requires expensive surface facilities and the disposal of vast quantities of spent rock. Both pose significant economic and environmental problems. Moreover, raw product quality is poor compared to conventional crude oil; however, upgrading using conventional hydroprocessing techniques yields high-quality finished products.

The mining and retort method is an old approach that could benefit from new technology. Improved methods for spent shale remediation would clearly make this approach more acceptable. Improved retorting methods are also a priority. Innovations that allow oil shale to be processed at lower temperature without an increase in reaction time would result in improved economics and improved product quality.

An alternative process still in development, in situ conversion, has captured the industry's attention. Wells are drilled, and the oil shale reservoir is slowly heated to about 660°F, at which point kerogen is converted to oil and gas over months. Using an in situ conversion process at pilot scale, Shell has extracted a good quality middle distillate refinery feedstock, requiring no further upgrading. In order to contain nascent fluids, and to prevent groundwater from seeping into the reaction zone, Shell generates a "freeze wall" around the production area. Chevron has proposed a simpler technique that takes advantage of the low hydraulic permeability of oil shale formations to isolate heated process volumes from surrounding aquifers.

Because in situ conversion technology is just emerging, it is not yet clear which specific techniques can advance the state of the art over the coming decades. However, the efficient use of heat is almost certain to be an important issue. The ability to map the temperature and the saturation of generated oil and natural gas throughout the reservoir would enable advanced control strategies. It will also be useful to monitor the freeze wall or low permeability barrier, to ensure that there is no fluid mixing between the reaction zone and surrounding formations.

As a domestic source of transportation fuel, oil shale could compete with heavy oil and coal-derived liquids. Oil shale, heavy oil, and coal are all abundant in North America. Canadian tar-sand production is already commercial. Coal can be treated with coal-derived solvents and gaseous hydrogen at high temperature to produce high-grade synthetic crude oil. An advantage of oil shale is that it has the potential to produce a superior liquid fuel product. However, the direct and indirect costs for fuel production from oil shale have yet to be fully evaluated.

The estimated time frames in which the commercial application of potential advances in oil shale technologies occur are listed below.

- 2010—None.
- 2020—Improved methods of shale remediation; innovative surface retort architecture and chemistry; and pilot scale in situ conversion methods.
- 2030—Large-scale oil shale production.

UNCONVENTIONAL HYDROCARBONS: GAS HYDRATES ◆

Gas hydrates constitute a class of crystalline compounds in which individual gas molecules reside within cages of water molecules. Gas hydrates are solids and have physical properties similar to those of ordinary ice. They form when a hydrocarbon gas, such as methane or a natural gas mixture, comes in contact with liquid water at high pressure and low temperature.

Gas hydrates are found within and under permafrost in arctic regions. They are also found within a few hundred meters of the seafloor on continental slopes and in deep seas and lakes. The reservoir architecture, technology needs, and eventual economic importance of hydrates in arctic and marine environments may be very different. Therefore they are considered separately in this report.

Arctic Hydrates

Gas hydrates are found within and beneath permafrost on the North Slope of Alaska, in the Canadian arctic, and in northern Siberia. Some of these accumulations are in areas where there has been significant conventional hydrocarbon development, with associated modern seismic and well-data surveys. In those areas, resources have been quantitatively evaluated. The results suggest that arctic hydrates have the potential to become economically viable sources of natural gas.

The best-documented Alaskan accumulations are in the Prudhoe Bay-Kuparuk River area. These contain about 30 trillion cubic feet of natural gas, which is about twice the volume of conventional gas found in the Prudhoe Bay field.[25] The proximity to highly developed oilfield infrastructure makes the Prudhoe-Kuparuk accumulation particularly attractive. The absence of a natural gas pipeline to market means that currently the gas is stranded. However, even without a pipeline, this resource may possibly enable the development of the nearby Schrader Bluff and Ugnu heavy oil reservoirs, which together amount to about 25 billion barrels of original oil in place.

The main technology barrier is the lack of validated methods for economically viable natural-gas production from hydrates. An arctic site capable of supporting multi-year field experiments would provide an opportunity for significant progress beyond the present state of knowledge.

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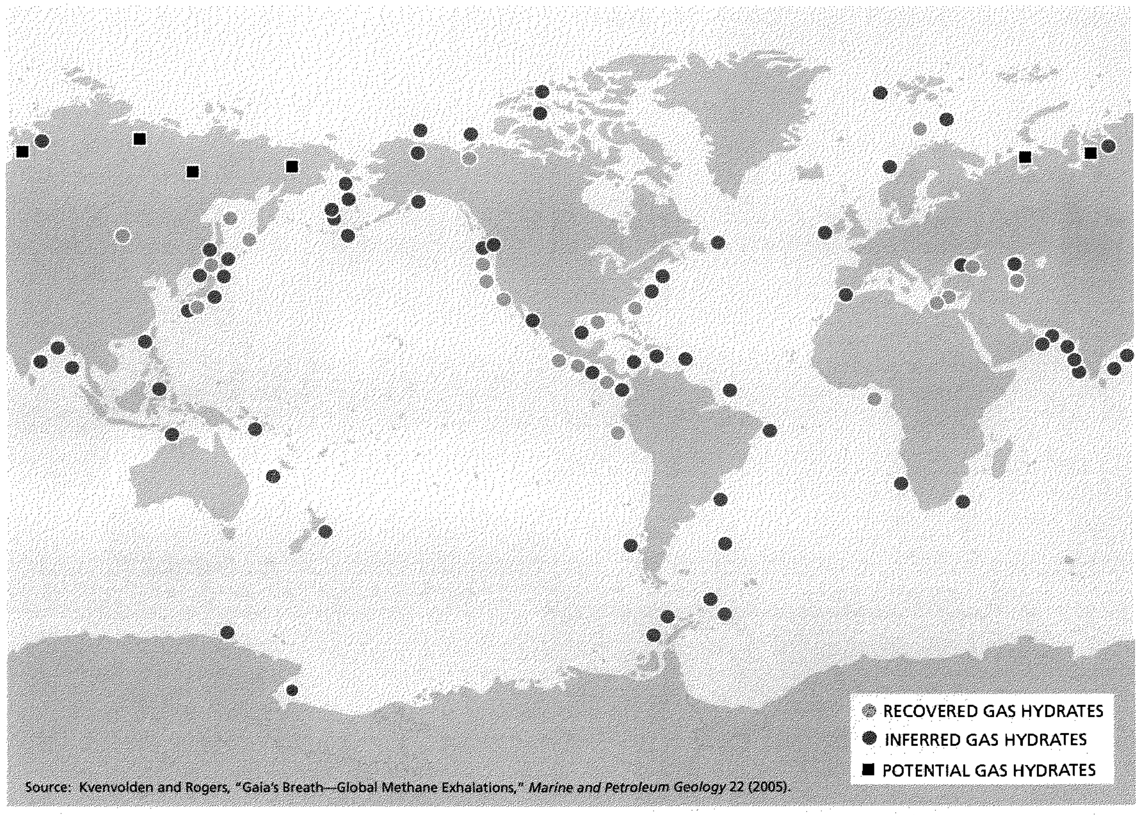
[25] Collett, TS, "Energy Resource Potential of Natural Gas Hydrates," *AAPG Bulletin* 86 (2002): 1971–1992.



Source: Kvenvolden and Rogers, "Gaia's Breath—Global Methane Exhalations," *Marine and Petroleum Geology* 22 (2005).

FIGURE 3-21. *Sites where Natural Gas Hydrates have been Recovered or are Inferred*

Marine Hydrates

A widely quoted USGS estimate predicts that there is twice as much organic carbon in gas hydrates as in all recoverable and unrecoverable conventional fossil fuel resources, including natural gas, coal, and oil.[26] Much of this endowment has been thought to be located on continental slopes in close proximity to major energy-consuming nations (Figure 3-21).[27] Estimates of hydrate-bound gas abundance have been repeatedly scaled back over the years, although large uncertainties remain.[28, 29]

Worldwide, only a few dozen boreholes have been drilled to assess marine hydrate resources. Most of these boreholes were drilled offshore around Japan in 2004,[30] and offshore from India in 2006. Comprehensive reports of these campaigns are not yet in the public domain, so there is a scant record available on which to assess the efficacy of exploration paradigms. Thus, the main technology barrier is the lack of validated means of reliably finding significant marine gas hydrate resources. A multi-site geological and geophysical exploration program, followed up with a multi-site drilling campaign, would accelerate the assessment of marine gas hydrates as an energy resource.

The estimated time frames in which the commercial application of potential advances in gas hydrate technologies occur are listed below.

- 2010—None.
- 2020—Production methods for arctic reservoirs developed through field tests and reservoir simulation; and broad-based exploration and delineation of gas hydrate resources in U.S. waters.
- 2030—Production methods for marine gas hydrates.

COAL TO LIQUIDS

In addition to direct combustion to produce heat and power, coal can be used as a feedstock for producing liquid and gaseous fuels. The Coal-to-Liquids Topic Report presents the issues associated with—and the potential for—coal-to-liquids (CTL) and coal-to-gas (CTG) technologies. CTL and CTG offer an opportunity for the United States to reduce its petroleum imports by producing petroleum products, such as diesel fuel and gasoline, from domestic coal resources. The primary technology reviewed is CTL; most reports have focused on CTL due to the cost and transportation issues associated with CTG. The other important objective included in the Topic Report is viewing and understanding the inputs and assumptions from various publications and the range of production estimates from CTG and CTL technology. A large uncertainty exists for CTL due to various assumptions including petroleum price and technological abilities. The quality of coal and the technological ability of converting the coal varied among the studies. Key assumptions were left unexamined, such as product transportation, labor, equipment availability, and environmental risk.

Overall, the published CTL production estimates are small in the total global petroleum market perspective. Even in the most optimistic scenario from the Southern States Energy Board (SSEB), the volume from CTL amounts to only 20 percent of the U.S. petroleum market.[31] The National Coal Council (NCC) indicated a 10 percent market share,[32] whereas various EIA scenarios had 0 to 6 percent of the U.S. market share.[33] The NCC and SSEB both mentioned the added benefit of using the CO_2 for enhanced oil recovery (EOR), however the increased oil volumes directly associated with using CO_2 from CTL are left unmentioned in those reports. The Topic Report discusses each of these reports in depth.

Even though the production estimates are small relative to the overall petroleum market, the incremental gains from this technology added to gains from other technology areas, such as oil shale, could have a significant effect on U.S. energy cost and import dependency. The use of coal provides the added benefit of relying on a resource that is more plentiful domestically than petroleum. However, this reliance must be carefully balanced with the economics of developing the resource, since CTL facilities can cost more than $1 billion for each 10,000 barrels per day of production. This has implications for the competitiveness of the U.S. economy within the global economy.

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[26] Kvenvolden, KA, "Gas Hydrates—Geological Perspective and Global Change," *Reviews of Geophysics* 31 (1993): 173–187.

[27] Kvenvolden, KA and Rogers, BW, "Gaia's Breath—Global Methane Exhalations," *Marine and Petroleum Geology* 22 (2005): 579–590.

[28] Milkov, AV, "Global Estimates of Hydrate-Bound Gas in Marine Sediments: How Much Is Really Out There?" *Earth-Science Reviews* 66 (2004): 183–197.

[29] Klauda, JB and Sandler, SI, "Global Distribution of Methane Hydrate in Ocean Sediment," *Energy & Fuels* 19 (2005): 459–470.

[30] Fujii, T et al., "Modes of Occurrence and Accumulation Mechanism of Methane Hydrate – Result of METI Exploratory Test Wells Tokai-oki to Kumano-nada'," *Proceedings of the Fifth International Conference on Gas Hydrates*, Trondheim, Norway (2005).

[31] "American Energy Security: Building a Bridge to Energy Independence and to a Sustainable Energy Future," The Southern States Energy Board, Norcorss, Georgia (July 2006). Accessible at www.americanenergysecurity.org/studyrelease.html.

[32] "Coal: America's Energy Future," The National Coal Council, Washington, DC (March 2006). Accessible at nationalcoalcouncil.org/report/NCCReportVol1.pdf.

[33] "Annual Energy Outlook 2006 with Projections to 2030," Energy Information Administration (February 2006). Accessible at www.eia.doe.gov/oiaf/archive/aeo06/index.html.

The primary routes for converting coal to liquid products are called *direct* and *indirect liquefaction*. Both technologies were used by Germany to produce fuels before and during World War II (direct liquefaction more extensively).

From the 1970s through the early 1990s, the U.S. Department of Energy conducted research and development related to direct liquefaction. Plans to construct large demonstration plants based on direct coal liquefaction were cancelled during the 1980s, in response to concerns about technical risks, increasing estimates of investment costs, and decreasing world oil prices. Additionally, fuels generated by direct liquefaction are rich in high-octane aromatics, but current clean-fuel specifications in the United States limit the benzene and aromatics content, and the toxicity of gasoline.

In the early 1980s, South Africa's Sasol Company expanded its 1950s production base by building two large indirect coal-liquefaction facilities. Currently, these two Sasol facilities produce a combined total of about 150,000 barrels per day of fuels and chemicals using coal as the primary feedstock.

Dakota Gasification Company's Beulah plant produces about 170 million cubic feet per day of substitute natural gas from lignite. In 2000, the plant began exporting CO_2 for use in EOR. Currently, about 95 million cubic feet per day of CO_2 produced at the plant are transported via a 205-mile-long pipeline to EnCana Corporation's Weyburn oil field in southern Saskatchewan. The CO_2 is used for enhanced oil recovery, resulting in 5,000 barrels per day of incremental oil production, or an additional 130 to 140 million barrels of oil over the life of the project. The Weyburn field is the subject of a long-term monitoring program to assess the final disposition of the CO_2 being injected in this project.

Engineering analyses indicate that co-production or *polygeneration* plants may offer superior economic and environmental performance, as compared to separate dedicated fuels-only plants. The co-products most often considered in previous projects and studies have been electric power and liquid fuels, usually diesel, produced through a process developed by Fischer and Tropsch.

No commercial scale CTL plant has been sited or permitted in the United States. Given that these plants will have aspects of both a refinery and a power generation facility, it is not clear how quickly this untested permitting process can be expedited, particularly if opponents intervene aggressively. These potential delays have associated financial risks to the first plants.

Unfortunately, at the time of this writing, many large construction projects, including GTL, are experiencing dramatic capital-cost increases from rising material costs, skilled-labor shortages, and contractor backlogs. It is unclear how long this current trend will continue. If these escalations are cyclical, their effect on future CTL growth may be marginal. Otherwise, they may have a pronounced effect on the construction of CTL, especially in the developed world.

The various reports used to predict the production outlook for coal-to-petroleum products differed in production range, and all seemed to be missing discussions on many significant fundamental variables required to develop a sound economic decision. The reports discussed variables such as labor, equipment, product transportation, environmental risk, and feedstock only briefly, if that. Though the reports had significant analyses showing the large untapped resources of coal, practicalities for actually making the coal available—such as labor issues and the price impact of greater demand—should be investigated further before launching a significant coal-to-liquids program.

BIOMASS ENERGY SUPPLY ✦

Some forecasters have expectations that renewable resources will be able to play a significant role in satisfying future energy demand. Others have a more pessimistic view and forecast that they will not make up even 2 percent of the total energy mix by 2030.[34] At issue is whether agriculture and forestry sources can supply food and fiber as well as significant energy needs for a growing population.

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[34] McNulty, S, "An Unsustainable Outlook," *Financial Times*, Oct 20 2006: 1.

In 2001, global primary energy consumption was 396 quadrillion Btu per year (Quad).[35] Of this total, biomass supplied 43 Quad. This is significantly more than the 2 percent predicted to be used by 2030, but is probably overlooked because about 37 Quad of this was from traditional heating and cooking. Global biomass production on the Earth's land surface is equal to 4,320 Quad, of which half is lost by autotrophic respiration and decomposition, leaving 2,160 Quad.[36] This still would indicate that there is considerable potential for biomass to play a role of some type in global energy production beyond heating and cooking.

Numerous studies have been carried out to determine the global biomass production that could be used to meet some of the world's energy needs.[37] All of the studies have had to deal with the variety of paths that biomass takes in the modern world, and have had to deal with estimates of global population, changing diets, and changes in crop yields. A recent report by the Food and Agriculture Organization of the United Nations (FAO) has estimated population, food needs, and agricultural development for the time between 2015 and 2030.[38] The report covers many of the pertinent factors that will determine whether sufficient agricultural output will be available for providing food, fiber, and fuel in the future.

According to the FAO, agricultural production of food and feed will continue to grow at a pace to meet the needs of the world population through 2030. Population growth will continue to decrease during this time period and on into the next century. Over the last 40 years, food production has been controlled by demand rather than supply, leading to a decline of almost 50 percent in the value of commodity crops—in constant dollars—over this time period. This has had a dramatic effect on crop productivity globally: crop yields and production have reached the highest levels only in countries with farm support programs, while third-world production has lagged.

Over the last 20 years, many studies have been carried out looking at the potential of agriculture to produce both energy and food for the world, if such production were optimized. While these studies have had varying conclusions, most estimate between 237 and 474 Quad of biomass energy could be produced while still feeding a growing world population. The most optimistic studies have as a criterion that the global agricultural food production per hectare, under equivalent environmental conditions, reaches optimal levels. This condition would allow large areas of land to become available for energy-crop production. If only waste biomass and dung were used from our current agricultural production, an energy supply of ~95 Quad could be expected.

Biotechnology is predicted to increase crop production in the next few decades at a faster-than-historical rate. This increase is being brought about by marker-assisted breeding, which can increase trait development by a ten-fold rate over conventional breeding. Along with this increased breeding rate, the ability to engineer specific new traits into crops will bring about remarkable changes in crop production. This increase could be expected to double the average yield of crops such as corn by 2030.

Such an increase in the U.S. corn crop would allow U.S. corn production to reach 25 billion bushels, compared with 11 billion bushels produced in 2005. A corn crop of that size would make it possible to produce 54 billion gallons of ethanol by conventional means, 6 billion gallons of biodiesel from the corn oil, and 21 billion gallons of ethanol from the excess stover (e.g., stalks). On top of all of this, 154 million metric tons of distiller's dried grain would swamp the animal feed market that is currently being met by corn and soybean production.

Many of these predictions require that some pressure be brought upon agriculture to spur production globally. The energy market could provide this new opportunity for agriculture by speeding investment in production. The development of new energy crops has the potential to produce even more bioenergy per hectare with fewer inputs and more environmentally friendly production means. This will not happen without the development of local conversion methods and logistics for efficiently handling the low energy density of most biomass feedstocks.

In the past, first-generation biomass conversion to fuels has been based on crops like corn, sugarcane, and soybeans, which are also food sources. Developing second-generation biomass conversion technologies in the future, such as cellulosic ethanol that uses trees and plant waste as a feedstock, would—if technically and economically successful—allow non-food vegetation to become fuels and improve the energy balance. Energy balance is the ratio of the energy output obtained from a given energy input.

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[35] Biomass energy is often measured in exaJoules (EJ), where 1.055 EJ is about a Quad.

[36] Smeets, EMW, Faaij, APC, Lewandowski, IM and Turkenburg, WC, "A Quickscan of Global Bio-energy Potentials to 2050," *Progress in Energy and Combustion Science* 33 (2007): 56–106.

[37] See Biofuels Topic Report for the full list of reports examined.

[38] Bruinsma, J (editor): *World Agriculture: Towards 2015/2030, An FAO Perspective*. Earthscan Publications Ltd., London (2003).

As with any newly developed energy sources, certain technical, logistical, and market requirements must be met for biofuels to achieve any significant scale. Challenges include: expanding rail, waterway, and pipeline transportation; scaling-up ethanol production plants and distribution systems; developing successful cellulosic conversion technology; and dealing with water and land-use issues. Collecting and utilizing the largest amount of potential biomass for conversion into fuels will need new technology development. This includes converting the biomass into a storable, stable form near its production site. That material would be shipped to a facility that can convert it into its final fuel form. This technology should optimally be able to take a variety of feedstocks in wet or dry form. The logistics of collection will demand such a complementary conversion technology.

While agriculture and forestry look like environmentally sound future-energy sources, this will only be true if it is done sustainably. This requires a systems approach to ensure that the natural resources at our disposal are not depleted. Closed-loop systems with energy production linked to meat production from the process wastes and methane production from the animal wastes generated are attempts at such systems. Much research must be done to truly understand what the consequences will be of these different options.

NUCLEAR OUTLOOK AND ITS IMPACT ON OIL AND NATURAL GAS ◆

Nuclear power is a significant contributor to the world's energy supply, representing about 6 percent of all energy utilized, and about 16 percent of the world's electricity. Nuclear power is projected to grow in the future, but this growth could be hampered by adverse public perceptions, policies, and economics.

In power generation, nuclear power is an asset that provides base-load electric power, meaning that nuclear power plants are operating at or near capacity all the time. This type of power generation does not typically compete with generation from traditional oil and natural gas power, which are typically load-following: that is, they are able to quickly increase or lower the amount of power supplied based on fluctuations in electricity demand. It is because of these different types of power systems that nuclear power displaces a much greater amount of coal-power generation growth and a smaller amount of oil and natural gas generation.

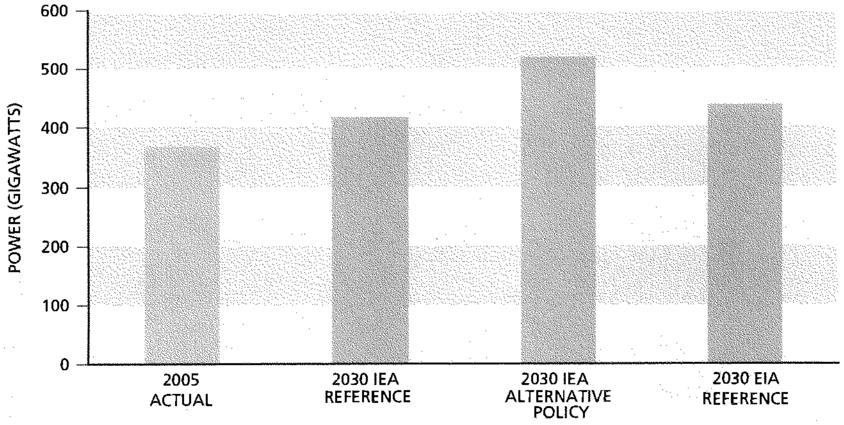
Over the past 40 years, nuclear power has emerged as a significant source of electricity. The majority of today's operating nuclear power plants were constructed during the 1970s and 1980s. However, because of high capital costs and a lack of public acceptance due to safety concerns, new nuclear power plant construction has significantly declined from its peak of 200 gigawatts during the decade of the 1980s.

Many forecasts show nuclear power increasing in amount of power generation, but declining as a percentage of total electricity generated. The majority of nuclear power plant construction is projected to be in non-OECD countries, with the majority of growth forecast in Asia. The period before 2030 forecasts that nuclear power will use existing technology fissile reactors, with more advanced technologies coming online after 2030.

The 2006 IEA World Energy Outlook has a "business as usual" reference case and an alternative policy forecast (Figure 3-22). The alternative policy case assumes that there is an effort to curtail global warming that includes measures to boost the role of nuclear power. The reference case forecasts for 2030 that nuclear power growth will trail alternative methods of power generation by about 3 to 1. The percentage of total electricity produced declines from 16 percent to 10 percent. In the IEA alternative policy forecast, nuclear power grows at a more rapid rate, but it is still outpaced by alternative power generation technologies, declining from 16 percent to 14 percent of total electricity generated.

The 2006 EIA International Energy Forecast is a "business as usual" scenario, with growth in non-OECD countries offset by decommissioning of nuclear power plants elsewhere.

With the current forecasts for nuclear power growth, it is believed that there is sufficient uranium as fuel and that the infrastructure could be constructed to



Sources: Energy Information Administration (EIA), *International Energy Outlook 2006;* and International Energy Agency (IEA), *World Energy Outlook 2006.*

FIGURE 3-22. *Projected Nuclear Power Growth, 2005 to 2030*

support the level of growth indicated in the forecasts. If growth is significantly higher than forecast, there is a possibility that the supply chain for critical nuclear components will need additional time to increase their manufacture.

Four issues can delay new nuclear construction. First is cost: the high capital costs for nuclear power plant construction, the financing required to construct these plants, and the resulting cost of energy often make new nuclear construction a difficult investment decision for a utility. There are government measures both domestically and abroad to encourage new construction of nuclear plants. One significant measure that would increase the competitiveness of nuclear power would be a pricing mechanism on CO_2; a CO_2 mechanism could result in a faster rate of adoption of nuclear energy than forecast.

The second issue facing nuclear energy is the storage and processing of spent fuel; waste management must be a strategic part of any nuclear development plan. The third issue is public perceptions around nuclear power safety. Fourth, there are global concerns about the proliferation of nuclear materials. If these four issues are not addressed, it is likely that nuclear power will grow at a global rate that is slower than the forecasts.

TRANSPORTATION EFFICIENCY

Advanced technologies have the potential to reduce petroleum fuel demand for the five subsectors of transportation (light duty vehicles, heavy duty vehicles, air transport, marine shipping, and rail transport) between now and 2030. Over time, new technologies will enter the marketplace if one or more of the following occur:

- The technologies mature and costs decrease
- Fuel costs increase and remain high
- The technologies are valued by the consumer
- Policies encourage adoption of improved technologies.

Government and industry play important roles in filling and maintaining the technology pipeline for transportation efficiency, can encourage academic research in high-profile transportation-technology areas such as advanced batteries and bio-based fuels, and can encourage students to enter engineering, science, and mathematics professions to work on these challenging issues. In addition, increased funding of R&D increases the number of breakthrough concepts that can be pursued, making the odds more favorable for some to he successfully commercialized.

The various modes of freight shipment have different energy requirements on a ton-mile basis, as do the various modes of passenger travel (automobiles, buses, trains, and aircraft). Policies that encourage efficient use across transportation subsectors were not addressed in the Transportation Efficiency Topic Report, and the costs, benefits, and hurdles of mode-shifting should be studied further.

Finally, alternative fuels have a generic impact across all of the subsectors by displacing some petroleum-based fuel, but have little effect on reducing the energy demand (e.g., Btu per mile) for a subsector. Hydrogen—when used as an energy carrier in fuel cells—and electricity, in plug-in hybrids or battery-electric vehicles, result in higher efficiency than existing technologies. Infrastructure requirements and the energy required to produce the fuels should be considered for these alternatives (e.g., well-to-tank assessment).

U.S. fuel demand for the five transportation subsectors, shown in Table 3-16, is based on EIA projections and is defined as the Reference Case in the Topic Report. Subsectors are discussed here in their order of the percentage of transportation demand. In all of the transportation subsectors, fuel consumption was considered at the end-use point (e.g., tank-to-wheels for the light duty vehicle sector). Energy is required to produce the fuels associated with the various transportation modes. These well-to-tank energy requirements can be substantial for some alternatives to petroleum (i.e., hydrogen, biofuels, and electricity, depending on the source). The Topic Report contains detailed tables of potential advances and their impacts for each subsector.

General Conclusions

The study team concluded that technology can make a significant difference in improving transportation efficiency. The light duty vehicle sector offers the greatest opportunities, but also has a number of challenges. Technology hurdles, costs, and potential infrastructure investments are some of these. In addition, the ways that consumer preferences affect the deployment of various technologies are complex. For the other sectors, a sound business case affects the deployment of technology, including fuel cost savings and operational factors.

It is important that all of the technologies are analyzed from a wells-to-wheels efficiency and cost basis. This was not done in the Topic Report, because the focus was on transportation efficiency at the point of end use (excluding fuel availability, production, and distribution issues).

It should be noted that, although the technologies discussed below are analyzed from a U.S. perspective, they are generic and can be applied in all parts of the world, when the appropriate attributes and constraints are considered for the specific countries of interest.

Sector	Quadrillion Btu Per Year		Percent of Transportation	
	2005	2030	2005	2030
Light Duty Vehicles	16.28	22.98	61.6	60.5
Heavy Duty Vehicles	5.65	8.73	21.3	23.0
Air	2.81	4.15	10.6	10.9
Marine	1.06	1.12	4.0	3.0
Rail	0.67	0.97	2.5	2.6
Total	26.47	37.95		

TABLE 3-16. *EIA Reference Case—U.S. Transportation Fuel Demand*

Light Duty Vehicles

The EIA reference case projects that, in 2030, technology improvements will result in ~13 percent improvement in new vehicle fuel consumption from 2005 levels. It is estimated that this includes technological improvements of ~30 percent at constant vehicle performance, and vehicle attribute changes that reduce this improvement by about half. Based on this study's analysis, technologies (drive train and body improvements, and hybridization) exist, or are expected to be developed, that have the potential to reduce fuel consumption of new light duty vehicles by 50 percent relative to 2005 vehicles. This assumes constant vehicle performance and entails higher vehicle cost. The extent to which these technologies translate into reduction in fuel consumption depends on factors not evaluated in this study, including customer preferences, vehicle and fuel costs, and vehicle attributes (acceleration, weight, size). Improvements beyond 50 percent will require breakthroughs in batteries or fuel cells, potentially resulting in significantly higher vehicle costs and significant infrastructure investments.

Technologies such as hybrids and fuel cells will take longer to deploy in the fleet than more conventional changes (such as improved fuel injection or turbocharging). Hydrogen for fuel cells would displace petroleum-based fuels. However, the source of the hydrogen, costs, technical hurdles, and infrastructure requirements are major unknowns and it is difficult to estimate the impact of fuel cells in 2030.

Heavy Duty Vehicles

Technologies exist to reduce new heavy-duty-truck fuel consumption by 15 to 20 percent in the United States by 2030, which is about equal to the EIA reference case. These technologies (e.g., engine efficiency, rolling resistance, and aerodynamic improvements) will involve higher cost and require an associated financial business case. Operational improvements such as reduced idling and improved logistics can provide a benefit of 5 to 10 percent across the fleet during this period. Advanced technology solutions, such as hybridization and fuel cells, offer fuel consumption reductions of an additional 25 percent, and applications would likely be initiated in local-delivery, short-haul, medium-duty delivery trucks and buses. In the near term, U.S. heavy-duty emission standards will limit the potential to reduce fuel consumption.

Air

Fuel consumption improvements on the order of 25 percent are the basis for the EIA reference case. This is an aggressive projection and all of the known technologies appear to be included in the EIA estimates. New technologies will need to be discovered to achieve additional improvements in efficiency. These new technologies will require a reinvigoration of U.S. research, development, and demonstration initiatives, similar to programs currently being carried out in Europe.

Marine Shipping

The EIA reference case is based on a 5 percent improvement in marine shipping fuel consumption by 2030. This level of improvement is achievable with operational solutions and existing technologies. Improvements greater than 5 percent will require new hull designs and new propeller designs. Given the long life of ships (greater than 20 years), migration of these solutions into the fleet will not have a large impact until later in the study period. Operational changes, affecting the entire fleet, may be more significant than technological improvements.

Rail Transport

The EIA reference case assumes that fuel consumption will improve by 2.5 percent between 2005 and 2030. Incremental improvements in engine design, aerodynamics, and use of hybrids have the potential to reduce new locomotive fuel consumption by up to 30 percent over 2005 technology. Rollout of new technology into the fleet is slow due to low turnover and will be difficult to achieve during the years considered in this study. Emissions standards will tend to increase fuel consumption.

Chapter GEOPOLITICS 4

Abstract

The world energy map is changing. Projected energy demand will come increasingly from developing and emerging economies, as will supply. The global energy future is also distinguished by an increasing concentration of energy suppliers and demand centers, which are geographically further apart; requiring increased investment, longer transport routes, and raising security and environmental concerns. The emergence of new market players, new alliances, and evolving rules further complicates the global energy picture.

This chapter recognizes that the global energy resource endowment is, indeed, enormous, but also examines "above ground" risks such as access, resource nationalism, security concerns, political shifts, and environmental and security considerations. These can significantly affect the producibility, conversion, and deliverability of energy, and the timing of needed investments. The chapter also addresses implications of carbon constraints and seeks to recast calls for "energy independence" by endorsing opportunities for enhanced "energy security" in a truly global and inter-dependent energy market.

The outline of the Geopolitics chapter is as follows:

- How the world is changing
  - Dramatic growth in global demand
  - New patterns of trade
  - The pressures of globalization
  - Changing evaluation of risks
  - Governance and resource nationalism
  - The growing power of national oil companies
  - Climate change
  - Sustainable development and related policy challenges
  - Security and terrorism
  - Other risks and scenarios
- Implications for the United States
- Conclusions

International energy trade is increasingly influenced by geopolitical considerations at the expense of the free play of open markets and commercial actions by a competitive oil and gas industry. As demand grows, oil and natural gas become strategic commodities susceptible to being used for geopolitical leverage. Alternative energy sources have the potential to become viable substitutes, but making them available at a scale that reduces global dependence on fossil fuels will take time. Meanwhile, global competition for oil and natural gas is intensifying as new players enter the market; suppliers are increasingly seeking to exploit their resources also for political ends; and consumers are exploring new ways to guarantee sources of supply.

The growing influence of geopolitical factors on global energy trade has profound implications for U.S.

interests, strategies, and policy making as well as for the ways that oil companies conduct their business. Many of the expected changes could pose heightened risks to U.S. energy security, in a world where relative U.S. influence is likely to decline as economic power shifts to other rising nations. In years to come, security threats to the world's main sources of oil and natural gas may persist and possibly worsen.

In geoeconomic terms, the biggest impact will come from increasing demand for oil and natural gas from developing countries, which may outpace the development of new sources of supply, thereby putting pressure on prices. In geopolitical terms, the consequences of such an imbalance will be magnified by the fact that demand is rising most strongly in China, India, and other large emerging economies.

Key questions abound: Will competition for scarce resources lead to political or even military clashes among major powers? Will bilateral arrangements among nations become common as governments attempt to "secure" energy supplies outside of traditional market mechanisms? How far will countries go in using their national oil companies to further foreign policy and internal political objectives? Will non-market forces divert needed investment in the energy sector?

These developments are taking place amid rising hostility to globalization in large parts of the world, including many industrialized countries that benefit from it. The political will to complete multilateral trade negotiations is ebbing, with major trading nations turning to bilateral or regional preferential agreements that fragment world trade, increase costs, and diminish market efficiency. It is even possible that the global trading system itself may fracture from geoeconomic and geopolitical stress.

On the security front, the spread of militancy is likely to continue in some of the major oil producing regions. Terrorism and weapons proliferation (including nuclear arms and other weapons of mass destruction) will probably continue to grow, as may the risk of war. The impact would be particularly acute if this happens in the Middle East, with its vast and critical oil and natural gas resources.

Government policy making is also likely to be increasingly influenced by non-governmental organizations and other groups promoting environmental interests, demanding new policies to combat climate change and other issues such as human and labor rights violations, supported by shifts in public opinion. The result will be mounting pressure on international oil companies to conform to new regulations and/or voluntary controls, thus altering the economic and political order within which they operate.

HOW THE WORLD IS CHANGING

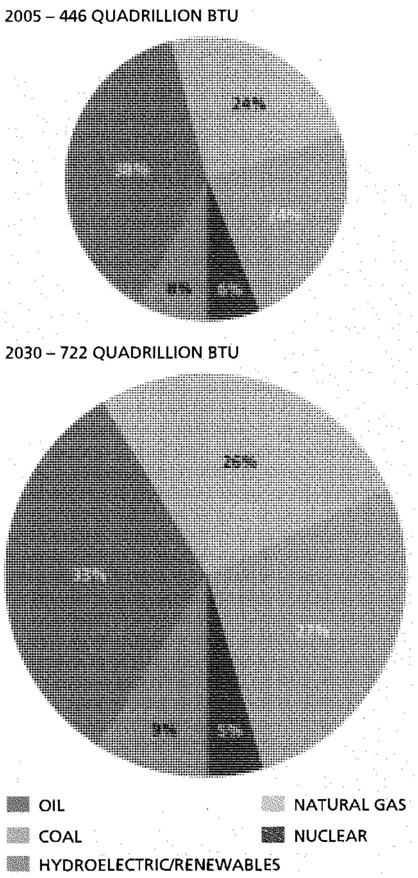
Dramatic Growth in Global Demand ◆

Current forecasts are for continued increases in global energy demand and changes in the pattern of energy flows, with a decided shift eastward on the "world energy map" due to higher demand in Asia. To appreciate the scale and pace of demand expansion, consider that it took world oil demand 18 years (1977-1995) to grow from 60 to 70 million barrels per day, but only eight years (1995-2003) to increase from 70 to 80 million barrels per day. If present projections prove accurate, demand could exceed 90 million barrels per day by 2010 and 115 million barrels per day by 2030.

Continued world population growth will lead to rapid increases in demand for food, housing, and other products and services that invariably require energy to produce and deliver. In addition, over a billion of the world's inhabitants currently have little or no access to the most basic forms of energy, an unsustainable predicament with potentially ominous consequences to the welfare of that population.

Most forecasts predict that during the next 25 years, the world will continue to rely essentially on the same forms of energy as it has for the past century—oil, natural gas, coal, and nuclear power—along with a broad range of renewable sources that includes solar, hydroelectric, biomass, and wind energy. Although global energy demand is forecast to double between 2001 and 2030, little change is expected in the relative shares of the major fuel sources (Figure 4-1) with over 80 percent of demand in 2030 projected to be met by fossil fuels.

Energy use in North America, which currently accounts for about 30 percent of worldwide consumption, essentially followed larger global trends. By contrast, greater reliance on nuclear energy in Europe slightly altered the total mix, with lower demand for coal and natural gas. In developing countries, often the least able to afford or employ the best available technology, fossil-fuel use approaches 90 percent.


2005 – 446 QUADRILLION BTU

2030 – 722 QUADRILLION BTU

Source: EIA, *International Energy Outlook 2006.*

FIGURE 4-1. *Global Energy Demand — Fuel Shares*

Given the long lead times necessary to develop and introduce new conventional fuel supplies and alternative energy forms, demand for fossil fuels (oil, natural gas, and coal) is expected to continue to dominate the global energy mix for at least the next two decades—absent radical changes in economic or foreign policies, environmental crises, terrorist or war devastation, or a major technological breakthrough.

The trend is particularly dramatic in tbe developing world. Both the International Energy Agency (IEA) and tbe Energy Information Administration (EIA) of the U.S. Department of Energy predict that developing countries in Asia, including China and India, will continue their current economic expansion, driving the doubling of energy demand in the developing world by 2030 (Figure 4-2).

New Patterns of Trade

As demand rises in Asia, a new global energy picture is emerging that requires an increased focus on investment, transportation infrastructure, security, environmental, and geopolitical considerations, as well as a reevaluation of overall strategies by government and industry.

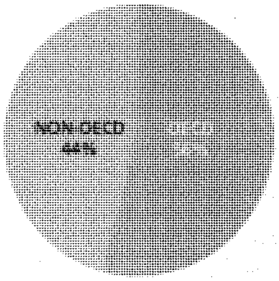
In the global oil and natural gas market, demand will continue to shift to emerging economies with growing populations. These nations will not only emerge as large energy consumers, but some will also control a large share of energy resources. At the same time, conventional oil and natural gas production in the developed world is declining.

The major regions of expanding production are the Middle East, West Africa, Russia, and the Caspian Sea, together with a few areas where unconventional production is rising (e.g., oil sands in Canada and extra-heavy crude in Venezuela). Tbe three major consuming areas are North America, Europe, and Asia.

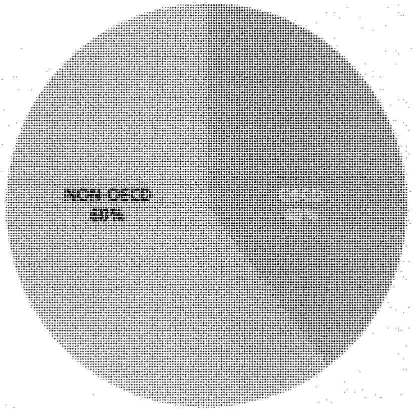
The growing need for transportation of energy between these areas raises important concerns over geographical "choke points," both for oil shipments and, increasingly, for natural gas—whether delivered by pipeline or in the form of liquefied natural gas (LNG). The most potentially congested, difficult, or dangerous transit passages, such as the Straits of Hormuz and Malacca and the Bosporus, pose both security and environmental challenges (Figure 4-3; see also Figure 2-76 in Chapter 2, "Energy Demand").

As patterns of demand and transportation change, new regional and international, commercial and strategic alliances may emerge, marking the beginning of a "new game" in the geopolitics of

2004 – 445 QUADRILLION BTU PER YEAR



2030 – 678 QUADRILLION BTU PER YEAR



Source: IEA, *World Energy Outlook 2006.*

FIGURE 4-2. *World Energy Demand Growth from 2004 to 2030*

oil and natural gas, in which different countries and corporations will develop new strategies and techniques to secure access to resources. Although the implications for international energy companies and smaller "independent" companies seeking to explore and produce oil and natural gas overseas—especially U.S. companies—are not yet fully evident, such companies may find themselves at a competitive disadvantage in gaining access to resources and new business opportunities.

Evidence suggests that this new game may already be under way. In the future, non-OECD nations will include both the largest holders of conventional energy resources and their fastest-growing consumers. The national oil companies (NOCs) and energy ministries in these countries will play an increasingly important role in policy decisions about how to develop their resources and whether to rely on the global market or instead to negotiate bilateral supply arrangements with other countries. These bilateral deals may include provisions that extend well beyond conventional commercial terms and require foreign aid and other commitments from the governments of consuming countries.

Energy's growing strategic importance may thus encourage producers to leverage their advantageous positions when dealing with consumer nations, either to gain commercial benefits or to further their national geopolitical or foreign-policy objectives. With shifts in bargaining power, the open-market rules and norms that have characterized global energy trade and investment for the past several decades may well be under threat. Yet all energy producers and consumers would benefit from greater investment and freer trade that open-market practices promote in an increasingly integrated world.

The Pressures of Globalization

For more than 60 years, growing areas of the world have enjoyed the fruits of expanding free trade and economic integration. Globalization has been driven by the communications revolution, the increasing ease of international financial movements, rising living standards, the continued opening of markets for products and services, the worldwide reach of multinational corporations, and other modernizing forces. The resulting unprecedented economic growth has been boosted by a global oil market that has relied on ready access to resources and the efficient application of investment capital, technology, and management by an internationally competitive petroleum industry. Many of these long-standing conditions, however, now face new challenges to their sustainability in the years ahead.

As new entrants such as China and Russia play an increasingly important role in the international economic system, the fundamental, Western-inspired values that have underpinned the system—representative government, the rule of law,

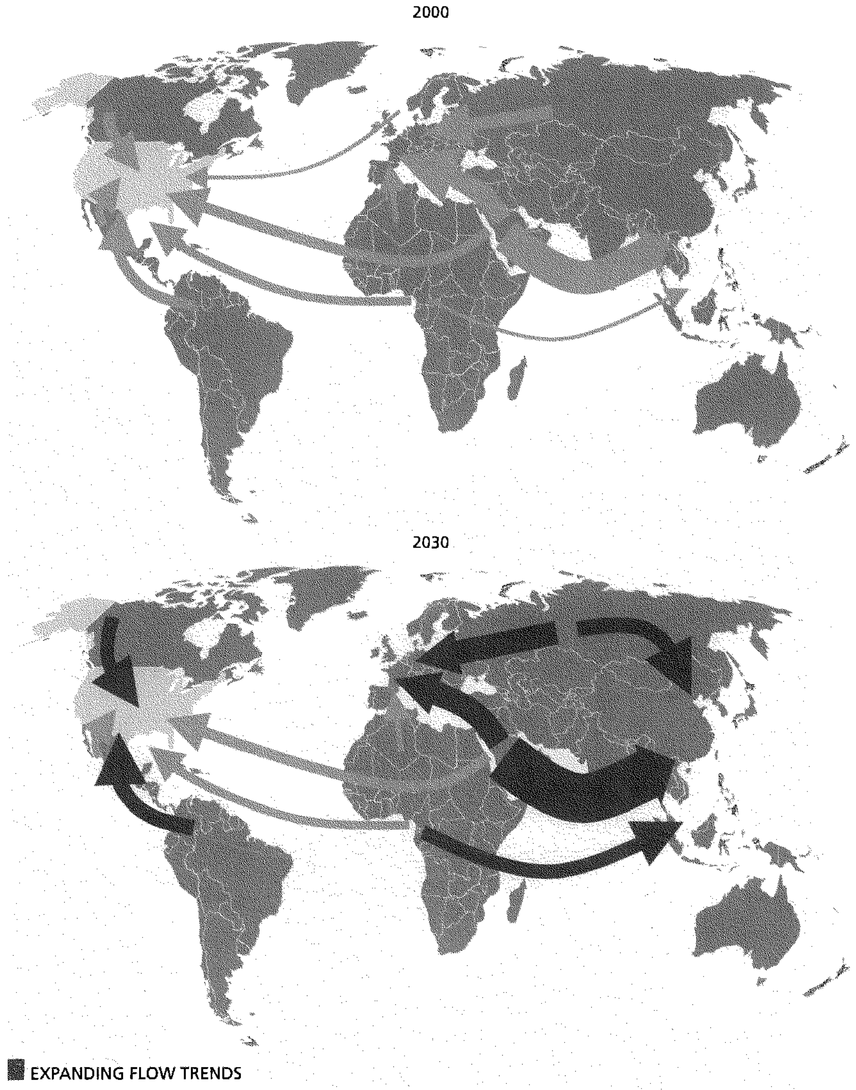


FIGURE 4-3. *Global Oil Flow Trends*

transparency, accountability, and open markets—can no longer be taken for granted. The balance of global economic power is shifting to emerging countries, not only to major, fast-expanding nations such as India and Brazil, but also to the main group of developing countries that populate the halls of international organizations such as the World Trade Organization (WTO), the international financial institutions, and United Nations agencies.

Increasingly, these developing countries are joining forces to increase their political clout. Not all are as committed to the principles of free trade, transparency, and the rule of law as the governments that founded the current world institutional framework after World War II. International institutions, and particularly the WTO, may have to adjust to the requirements and wishes of these new economic powers, as they assert increasing influence over the global agenda and the rules of the international trading system. Many international economists hope that as developing countries grow richer, they will increasingly appreciate the need for open markets and the rule of law in order to protect their own exports and growing prosperity.

If, however, moves toward more open markets stall, and even reverse, the world economy will become less efficient, costs will rise, and individual governments may apply their own rules to investments, taxation, and the way they select energy trading partners. There may be more preferential trading among regions and an increasing number of bilateral or regional deals struck for political rather than purely economic reasons. U.S. influence for resolving these problems would diminish if agreed multilateral rules are disregarded. Such developments are all the more likely as a worldwide backlash against globalization has been growing in recent years, not least in the Western countries themselves. Rising economic nationalism and protectionism at home would make it harder for the United States to continue to exert global leadership in favor of open markets.

Various countries and interest groups are resisting the forces of globalization and many of the international norms and institutions designed to facilitate the spread of liberal market systems. At one extreme, rising anti-Western and particularly anti-American sentiments and actions—as exhibited by militant movements, terrorism, and economic populism—pose fundamental threats to globalization. Whether resistance is directed against the pace of globalization, its perceived inequities or alleged failures, or its social/cultural impacts, countries and ideological movements often challenge the international system and the forces of economic liberalization.

It is unclear whether this resistance will ultimately slow, reverse, or otherwise alter the progress of globalization, or change the prevailing norms of the international system. Many opponents blame globalization for ills for which it is not responsible, although that does not necessarily diminish the political impact of their grievances. A prolonged and spreading backlash against globalization and international norms could threaten their long-term viability, thus introducing greater uncertainty and risk when energy investors and governments consider investment and management decisions.

Changing Evaluation of Risks

When evaluating global investment opportunities, international oil companies (IOCs) have traditionally relied upon an inventory of investment-risk criteria. In exploration and production ventures, these considerations typically comprise:

- Geological risk—are the hydrocarbons present?
- Technological risk—can resources be accessed with existing/available technology?
- Commercial risk—at what price, and under what terms? Are these adequate to ensure a favorable return on investment relative to shareholder and portfolio risk?
- Political risk—what threats do political conditions pose to the project and investments? What if the political situation changes? Can these risks be managed?
- Environmental risk—can the resources be developed in environmentally acceptable ways?
- Human-resource risk—are there enough suitably trained and qualified people available to develop the resources?

Some of these traditional assessments concern the location and nature of underground resources, others relate to "above-ground" risks, such as political and labor-market developments. As conditions for resource extraction change, however, it may well be that the "above-ground" risks pose greater challenges to meeting future global oil and natural gas demand than concerns over the resources themselves.

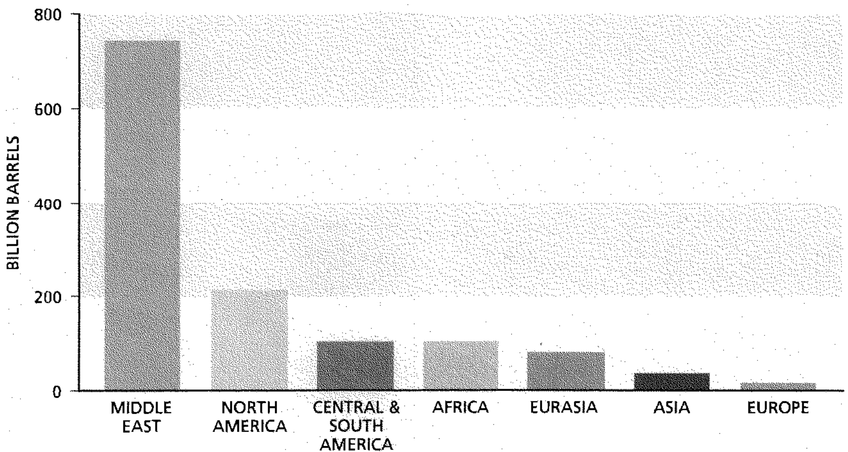
Such "above-ground" issues include conditions of access to resources, security, the kinds of investment required, transportation infrastruture, availability of skilled labor, the quality of governance and political stability in the country holding the resources, terrorism, corruption, and various environmental considerations. Over the past decade, investment risk has increasingly been reevaluated in the light of these factors, and it seems inevitable that this trend will intensify in coming years.

Governance and Resource Nationalism

Since at least the first half of the 20th century, host governments have attempted to take direct control of their countries' oil resources. Now, high global oil prices have encouraged a new wave of resource nationalism. Most recently, a new generation of sovereign governments has begun to reassert greater control over natural resources, in an effort to extract maximum commercial advantages—often by violating existing contracts. Sometimes, these governments also select partners on the basis of national geopolitical or broader economic priorities, rather than on open market competition. Increasingly, NOCs are operating outside their own countries or traditional areas and are competing internationally with the support of their governments.

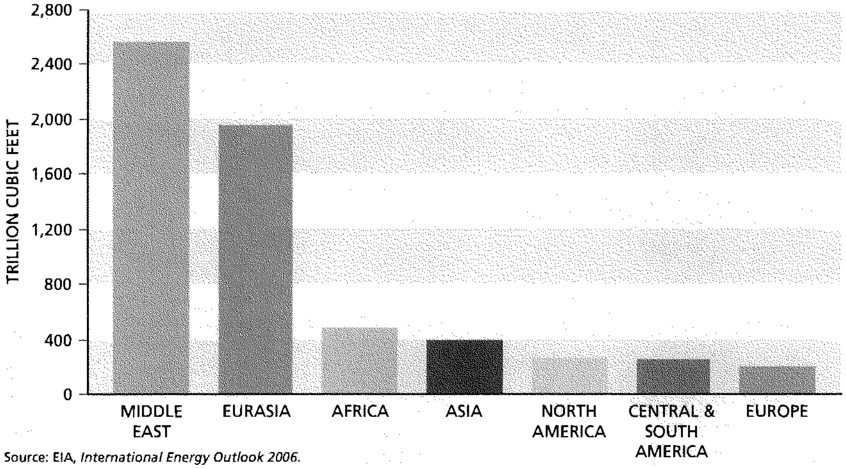
A predominant share of the world's known oil and natural gas reserves is not available for direct investment by international oil companies. These reserves are primarily in member countries of the Organization of Petroleum Exporting Countries (OPEC) located around the Persian Gulf, where resources are most plentiful and can often be developed at low cost (Figures 4-4 and 4-5). Countries outside the Middle East that once welcomed foreign investment, such as Venezuela and Russia, have turned increasingly hostile. Thus, investment capital, as well as the best industry technology and manpower, cannot be applied in the most economically effective manner to increase supplies of oil and natural gas for the world market, even at a time of historically high energy prices.

In a world of growing energy demand, producing countries are more inclined to dictate political or other conditions that often distort market efficiency. As Russia explores new ways to increase control over



Source: EIA, *International Energy Outlook 2006.*

FIGURE 4-4. *World Crude Oil Reserves — Regional Shares*



Source: EIA, *International Energy Outlook 2006.*

FIGURE 4-5. *World Natural Gas Reserves — Regional Shares*

investors and consuming markets, similar developments are occurring in Latin America, most especially in Venezuela. In Russia, resource nationalism is used to justify reversing privatizations and redistributing oil income, and often considered a desirable way to safeguard the nation's greatest natural assets from rapid "exploitation" by profit-maximizing international companies that would endanger national plans to stretch out use of the resources over as many years as possible. Russia and other countries also view energy as a means to increase their global influence.

However, resource nationalism undermines investor confidence in the long run and can lead to many undesirable results: deferred investment slows the pace of resource development; oil rents are diverted to unconnected social, political, or military activities; infrastructure and resource development are neglected; and the expertise available from international industry is rejected in favor of state control or cooperation with other NOCs.

High prices for producing countries—together with popular pressure for jobs and other government programs—further encourage resource nationalism and erode the sanctity of contracts. Consequently, investments in production capacity either slow or flow instead to areas of higher geological, technical, financial, and political risks. In some of these areas the phenomenon known as NIMBYism (from "Not In My Back Yard") or environmental concerns may further restrict access. Restrictions on timely investment in an industry with long lead-times prolong the normal cycles of the petroleum business. The result is to extend periods of supply shortfalls, as in the 1970s, and surpluses, as from 1984 to 1999, and to increase uncertainties, inflexibility, and consequent volatility in global energy markets.

The Growing Power of National Oil Companies

Over the last 30 years, national oil companies have become a major factor in the global oil market. Most owed their creation to a feeling in many resource-rich countries that their energy endowments would only be used for the national good if a national company were directly involved in the process. This was accomplished in various ways, ranging from seizing foreign-owned resources and facilities, to nationalizing with compensation, to creating new companies to participate in developing the resources. Many of the early NOCs (e.g., Aramco and Statoil) have grown into world-scale, efficient energy-market players operating globally in ways largely indistinguishable from IOCs. Because of non-commercial operating mandates or other local factors, other NOCs have remained inefficient or even marginal suppliers, and most operate only within their own borders.

With the increasing concentration of reserves in countries where NOCs have a dominant role by law, the future development strategies adopted by NOCs will play a key role in determining whether future oil supply meets expanding global demand. This will be even more important as reserves are depleted in other parts of the world or cannot be developed because of environmental, economic, or political constraints. NOCs from countries with growing oil imports, such as China and India, are increasingly participating in the global market, both to try to safeguard their own energy security and to foster other trade relationships.

With few exceptions, producing-country NOCs have proved to be reliable suppliers on the world market. Absent a fracturing of the global oil market, which would make political use of "the oil weapon" more feasible, NOCs may continue to develop in this way—if only to ensure access to the markets they want. The concern is, if bilateral energy deals become more common, governments may be tempted to achieve political or foreign policy objectives by utilizing their energy "leverage." A more immediate and important concern is whether sub-optimal development of resources controlled by NOCs could pose a major and long-term supply risk. Inefficiency could result from:

- Subsidized or below-market domestic product prices
- Diversion of revenues and deferral of investment for social purposes, or for other government uses
- Uncompetitive labor practices or government employment requirements
- Low levels of technology.

These disadvantages may be partly offset by low production costs, easy access to reserves, preferential regulatory treatment, and, in many cases, small dividends to shareholders. More generally, NOCs may have a competitive advantage when dealing with certain problems, largely because they are not accountable to shareholders in the same way as IOCs and because they often enjoy tangible advantages accorded by their national governments. On the other hand, if energy prices decline significantly, producing countries may once again need to attract foreign investment in order to maintain or increase production levels.

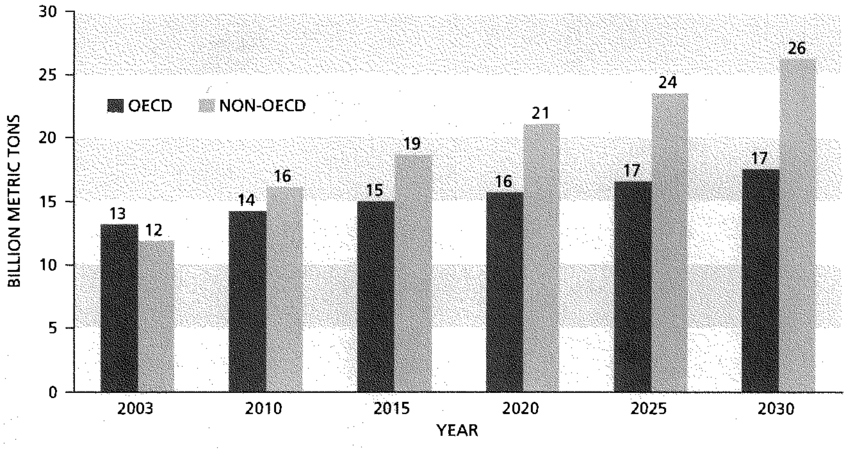
Climate Change ◆

Greenhouse gas emissions have hitherto come primarily from industrialized countries. In the future, emissions from emerging economies and the developing world are expected to increase dramatically, accounting for over 60 percent of new growth in global greenhouse gas emissions (Figure 4-6). Greenhouse gas emissions from the developing world will exceed those of the industrialized world before 2010.

Climate change and the policy responses it triggers will have significant effects on global oil and natural gas supply and demand. There is widespread agreement among climate scientists that the world is growing warmer, regardless of whether most of the temperature increase is due to human activities. As a result, national, state/provincial, and local governments, as well as companies are beginning to work toward a carbon-constrained future and are trying to anticipate its consequences. Growing consensus on the need for technological, policy, and commercial responses to rising temperatures, sooner rather than later, would ultimately have an effect on energy/fuel choices by both producers and consumers. Significant impacts fall into two general categories: the effects of climate change itself, and the effects of policy responses to it—notably the move to a carbon-constrained economy.

Climate Change

- Climate change will physically affect the supply of oil, natural gas, coal, and other fuels both positively and negatively; for example, as a result of longer ice-free periods in higher latitudes and lost ice roads.
- Climate change will increase or lower the demand for oil and natural gas as changing weather patterns modify seasonal demand for heating and cooling, and as changes in crop growth and water resources alter population patterns.
- If the earth becomes significantly warmer, pressures arising from population migrations, altered food supplies, and new growing seasons could create not only environmental but also security problems. The



Data Source: EIA, *International Energy Outlook 2006.*

FIGURE 4-6. *World Carbon Dioxide Emissions by Region, 2003-2030*

hardest hit countries are likely to be in the developing world, the biggest potential source of new waves of migrants and refugees.

Policy Responses and Carbon Constraints

- Policy responses to climate change, such as carbon taxes, cap-and-trade systems, and tougher efficiency and fuel standards, will affect both the supply and demand for oil and natural gas.
- Differing national responses could damage the international trading regime by distorting competition and provoking retaliation by other countries.
- It is widely agreed that significant reductions in human emissions of carbon dioxide and other greenhouse gases would require substantial innovation and the widespread deployment of new energy technologies, requiring large and sustained private and public sector investments in research, development, demonstration, and deployment.
- Many economists agree that the most cost-effective ways to reduce greenhouse gases involve broad market-based incentives to the private sector to undertake technological advances without governments mandating the technology chosen.
- Technological and policy efforts to meet energy-security and environmental goals are sometimes aligned, but often are not. For example, renewable biofuels may help meet both energy and environmental objectives despite raising food prices and creating disruptions in land and water use; whereas converting domestic coal and oil shale to liquid fuel may benefit energy security, but present significant environmental challenges.

Sustainable Development and Related Policy Challenges

Traditional concepts of economic development are being challenged by the growing movement in favor of "sustainable development." This term means different things to different people, resulting in widespread confusion over its definition. Often "sustainable development" is used simply as a call for greater attention to be paid to the environmental and social impacts of human activities. According to the United Nations' Department of Economic and Social Affairs Division for Sustainable Development, "sustainable development" is the type of investment that "meets the needs of the present without compromising the ability of future generations to meet their own needs."

Such an aim may conflict with market-based development strategies, particularly if it implies that restrictions would be placed on the behavior of economic actors, such as constraints on the use of non-renewable resources. In the energy sector, progressive adoption of "sustainable development" principles could result in increasing political pressure to move from non-renewable to renewable sources of supply—even in situations where it may make less economic sense than choosing a conventional fuel alternative. Some proponents for sustainable development reject fossil fuels completely, while others recognize they are needed until adequate alternative energy sources become widely available. Sustainable development strategies are also sometimes linked to proposed solutions to problems of energy poverty and the distribution of wealth.

Steep increases in oil prices have led to significant transfers of wealth from energy consumers to a small and increasingly concentrated group of energy producing nations. Large amounts of capital have shifted from OECD countries to non-OECD states, which may not have adequate institutional safeguards to protect against rampant corruption and misuse of these massive revenue inflows. Many resource-rich countries have no institutional capacity to distribute energy revenue equitably, or to use it to stimulate economic growth and diversity by developing and modernizing other sectors of their economies. In addition, the temptation to rely excessively on energy revenue while neglecting the rest of the economy (a condition sometimes referred to as "resource curse") can be a barrier to economic reform and a recipe for long-term economic failure.

Higher energy prices also widen the disparity in living standards between rich and poor nations. Wealthier countries have largely managed to cope with the price rise, while some developing economies have been forced to curb energy demand and to revert to use of non-commercial biomass, such as firewood. Other developing countries, however, have benefited from the current cycle of commodity price increases.

Increasingly, governments consider that these disparities in living standards reflect an unsustainable development path and may alter the way they approach natural resource development and revenue distribution. Concerns over the consequences of higher energy prices on developing and emerging or transitional countries could redirect energy investment from traditional fuels to alternative-energy technologies and services. Many countries, however, are unable to attract the latest clean-energy technologies because energy is not priced at market rates in the domestic economy.

The International Energy Agency's *World Energy Outlook 2006* estimates that over a quarter of the world's population (some 1.6 billion people) has no access to electricity. Global electrification is distributed very unevenly. The highest proportions of people without electric power live in large parts of Sub-Saharan Africa and in South Asia. Supplying electricity to these communities may drive up carbon dioxide production, further increasing concerns about climate change. Even when people live close to sources of energy production, as in the Niger Delta, they are often precluded from enjoying the potential benefits because of inadequate distribution systems, lack of needed investment, and ineffective government policies on pricing, revenue sharing, and resource regulation.

Security and Terrorism

During the past 20 years, increases in global energy demand and the elimination of uneconomic refining capacity have effectively depleted the once ample surplus in production and refining capacity. Stricter petroleum product specifications also absorbed a large share of investment capital and limited refining flexibility. This has created a tighter market in which instability, labor unrest, sabotage, or other threats to supply can drive oil prices sharply higher. In particular, global reliance on oil supply from the Persian Gulf puts a premium on security in a confined area with growing intra- and inter-state tensions emanating from the war in Iraq, Arab-Iranian rivalry, rapid social change, and religiously inspired radical groups that seek government overthrow.

Conflict in the Middle East is neither a recent phenomenon nor one that lends itself to quick solutions. While many argue that the Arab-Israeli conflict is not at the core of regional tensions, the persistence of the conflict and the polarization of opinions surrounding it keep the entire Middle East in a high state of tension. Current circumstances suggest that hostilities will persist—or perhaps even escalate—in the near term.

While overt war between countries of the Persian Gulf is unlikely, threats to and harassment of production facilities, refineries, terminals, and shipping remain a possibility. Extreme "resistance" groups seek to overturn the current order by means ranging from political activism to subversion and terrorism. Militants aim to remove many of the existing governments in the region and to drive Western powers and oil interests from the Middle East. While the likelihood of extremist groups actually taking over governments in the region is remote, there is a much greater possibility that non-governmental or para-governmental organizations could either disrupt supplies through the Strait of Hormuz or conduct a successful attack on a land-based facility.

If a radical group were to come to power in any Middle Eastern producing country, it might cease shipping oil to the United States or selling it to U.S. oil companies. Such restrictions would result in at least short-term supply disruptions that could put a small premium on oil destined for U.S. markets as other suppliers diverted their product in the global market.

Another threat could be heightened regional tensions as a result of nuclear proliferation in the Middle East. Iran's acquisition of a nuclear weapons capability, for example, could induce Saudi Arabia, Turkey, Egypt, and others to develop their own military nuclear capacity. In such a scenario, already high tensions in the region would be stoked by the threat of preemptive strikes or nuclear warfare. Should Middle East oilfields be seriously threatened, there would be sweeping consequences for world energy supplies and prices.

Other Risks and Scenarios

China and India are both concerned that the strains of unprecedented economic growth could trigger domestic political instability. Both countries must meet the energy demands of their rapidly growing economies and the development expectations of extremely populous societies. Failure to deliver on these expectations could lead to social unrest, but fulfilling these demands will also create huge economic, social, political, and environmental problems. Domestic coal is the most abundant and economic resource in both countries. It is often, however, used inefficiently and is subject to infrastructure bottlenecks such as those in rail transportation. Expanded use of coal would increase greenhouse gas emissions even more rapidly.

Although most current concern centers on high oil prices, a sudden price collapse could also cause instability in parts of the Middle East and other major producing countries, such as Russia, Mexico, Nigeria, Venezuela, and Angola. In the years ahead, Middle Eastern oil producers face relatively similar challenges: undiversified extractive economies, a youthful population seeking gainful employment, and political systems that are beginning to show signs of strain in large part because of insufficiently representative governments. While all these problems are becoming more acute, current high oil prices have taken much of the political urgency out of addressing them in the near term.

Apart from the petroleum sector, economies and trade are underdeveloped in most of the major oil producing countries, although in some localized areas construction is booming and capital markets are becoming more vibrant. About 40 percent of Saudi Arabia's gross domestic product (GDP) is still directly connected to the petroleum sector, as is 60 percent of Qatar's GDP and 30 percent of Algeria's. Government revenues are even more closely tied to the energy sector: petroleum exports account for 70 to 80 percent of Saudi Arabia's state revenues, about 80 percent of Kuwait's, and 40 to 50 percent of Iran's. High oil prices thus not only create a significant income for regional producers, but the windfall revenue disproportionately aids producing governments that rely almost exclusively on oil production rather than normal taxation for their income.

How these countries manage their substantial oil and natural gas profits, how long high prices will be sustained, and how far and how quickly they may fall, are all critical questions that will determine political risks in the Middle East over the next two decades. Where elections have been held in the region, extremists have scored some striking successes. Democratic elections are not by themselves a guarantee of political stability, which requires much more fundamental changes in governance, and social and legal systems, often over many years.

In addition, radical political movements are extending their influence across borders in an unprecedented manner, thanks in part to easy access to the international media that satellite television and the internet provide. Local populations are also being radicalized by fanatical religious leaders and by indoctrination in terrorist training camps. Finally, it is difficult to achieve stability in this critical oil-producing region without real progress in an Israeli-Palestinian peace process.

Outside the Middle East, many African countries and other under-performing economies are struggling to convert their energy wealth into economic development and diversification, whether through innovative energy-development programs in cooperation with the World Bank or by increasing social requirements on energy companies. Africa currently provides the United States with about 15 percent of its imported energy and may ultimately account for over 25 percent of U.S. oil and natural gas imports. However, continued and expanded U.S. access to African energy is by no means certain as other suitors are already lining up to secure future supplies. African trade with India and especially with China is growing rapidly. China's trade with Africa doubled between 2000 and 2004 and China is now Africa's third largest trading partner after the United States and France.

Chinese and Indian companies are competing aggressively with IOCs and providing more capital to develop African resources. This is a healthy development as long as investment projects are based on economic competition and are not attached to non-economic conditions. Corruption continues to pose a challenge to stable oil and natural gas production, especially in Africa, by misallocating precious resources and by discouraging long-term investment.

In Russia, the shifting roles played by private and state companies since the Soviet Union's collapse have stemmed investment flows and economic revival of the oil and natural gas industry. These problems have been exacerbated by policy swings between support for market competition and greater government control. Current policies show a strong preference by Moscow for reestablishing state control over energy resources and to use oil and natural gas supply as geopolitical tools to increase its influence in Europe and Asia. However, the vast investment needs of Russia's energy sector could still persuade the government to become a more market-oriented global player at some point in the future, particularly as world energy prices moderate.

In the Caspian Sea region, the competing interests of Russia, China, and the European Union continue to place heavy pressure on resource development and transit decisions. Ideally, a multiple pipeline strategy would include, simultaneously, expanding capacity along the Russian route, expanding shipments to China, and dramatically increasing shipments across the Caspian Sea to Western markets—either by a shuttle-fleet of more efficient oil tankers or, more ambitiously and controversially, by seabed pipelines for oil and natural gas. In that way, oil and natural gas could be delivered to the highest-value market without political or commercial restrictions.

It remains uncertain, however, whether such a multiple-pipeline strategy can overcome significant political and financial roadblocks. The cost-benefit calculations by host and transit states, and by foreign investors, will undoubtedly play a significant role in deciding the fate of these various routes. Nevertheless, delays in resolving these transit issues have already postponed delivery of significant oil and natural gas from the Caspian Sea region to world markets. Further delays would forestall the full development of this significant oil and natural gas potential.

IMPLICATIONS FOR THE UNITED STATES

Energy Security

For more than half a century, the United States has been the leader in global economic integration and a strong advocate for the free flow of goods, services, and capital to benefit both the American and the global economies. Throughout this period, the United States has been a net importer of oil. Domestic oil production peaked in 1970. In 2030, oil and natural gas will continue to dominate primary energy demand. The notion that the United States, as the world's largest energy consumer, can truly be rid of reliance on imported oil and natural gas is politically appealing, hut fanciful. "Energy independence," if it were to be pursued vigorously without taking into account economic consequences, could work at cross purposes to America's other international objectives and obligations in this increasingly interdependent world.

For globally traded commodities like oil, and increasingly for natural gas, significant supply disruptions in one part of the world affect all markets regardless of whether they seem to be directly involved. This interdependence was dramatically demonstrated by the global repercussions from

Hurricanes Katrina and Rita in 2005: storm damage to oil rigs and refineries in the Gulf of Mexico affected markets worldwide, and U.S. demand could only be met with the help of petroleum supplies from around the world. Other events that have disrupted supplies include, for example, militant activity in Iraq and Nigeria, and surges in market demand from developing countries such as China, India, and Brazil.

By the same token, in an integrated global energy market, the opening up of new resources in any particular region adds to overall global supplies and thus benefits all consumers, wherever they may be. Therefore, managing "energy *inter*dependence" is a worldwide geopolitical challenge, one in which the United States must play a constructive leadership role.

A more useful definition of energy security is required to help inform and shape the public policy debate. Such a definition would include:

- A competitive market
- Stable and diverse supply with minimal disruptions
- Low price volatility
- Adequate spare capacity and logistical infrastructure
- Diverse energy mixes
- Protection of the global environment, including climate considerations
- Flexibility to accommodate shifting demand patterns
- Transparency and reliability of commercial relationships.

Neglecting these objectives in a blind pursuit of energy self-sufficiency would risk unintended and harmful consequences for both energy suppliers and consumers alike.

As the price of energy rises, its political importance to both producing and consuming countries increases. Producers and consumers regard energy security from different perspectives. For major energy importers, supply security is a key concern because reliance on another country or third party for energy involves risk. Governments of consumer countries want to provide their citizens with energy services while protecting them from disruptions and major cost fluctuations.

Energy exporters, in turn, depend on stable demand and reliable access to consumers. Countries rich in natural resources arguably have greater control over their domestic energy security. But the ways that producer countries interpret the approaches their consumers take to secure greater energy assurance for themselves (demand-side management, promoting renewable fuels, etc.) can affect investment decisions by producer countries. These decisions, in turn, affect importing countries' energy security interests.

Energy security involves various perspectives and requires many potential solutions. These multiple possibilities make managing global energy flows extremely complex. Individual governments and companies have few tools to influence overall energy security. And yet, the interconnected nature of the global oil and natural gas markets means that decisions made by producer or consumer countries will affect the energy security of others.

Engagement and Cooperation

International cooperation is an important component of U.S. energy policy and a significant means by which Washington seeks to promote greater understanding of diverging perspectives and to foster agreement on common principles, shared priorities, and paths forward. International engagement and cooperation will become more important as geopolitical tensions continue to place stress on international energy markets and relationships between energy players.

Broad-based cooperation will ensure that global energy markets continue to function efficiently and to meet the energy needs of a growing global economy. U.S. programs should aim to:

- Expand energy production
- Improve energy efficiency
- Reduce damage to the environment caused by energy production and use
- Diversify the types, sources, and suppliers of energy
- Encourage efficient and flexible markets nationally as well as globally and avoid restrictions that impede their ability to adjust to any disruption
- Remove barriers to energy investment and trade
- Promote greater transparency in energy trade
- Invest in modernizing energy infrastructure
- Develop and deploy new technologies
- Protect global energy infrastructure.

PARTNERSHIP	GOAL	MEMBERS
Carbon Sequestration Leadership Forum	Development of improved cost-effective technologies for the separation and capture of carbon dioxide for its transport and long-term safe storage. The purpose of the CSLF is to make these technologies broadly available internationally, and to identify and address wider issues relating to carbon capture and storage.	Australia, Brazil, Canada, China, Colombia, Denmark, EC, France, Germany, Greece, India, Italy, Japan, Korea, Mexico, Netherlands, Norway, Russia, Saudi Arabia, South Africa, UK, United States
International Partnership for the Hydrogen Economy	Accelerate the transition to a hydrogen economy. The IPHE provides a mechanism for partners to organize, coordinate and implement effective, efficient, and focused international research, development, demonstration, and commercial utilization activities related to hydrogen and fuel cell technologies. The IPHE provides a forum for advancing policies, and common technical codes and standards that can accelerate the cost-effective transition to a hydrogen economy; and it educates and informs stakeholders and the general public on the benefits of, and challenges to, establishing the hydrogen economy.	Australia, Brazil, Canada, China, EC, France, Germany, Iceland, India, Italy, Japan, Korea, New Zealand, Norway, Russia, UK, United States
Generation IV	The Generation IV International Forum, or GIF, was chartered in May 2001 to lead the collaborative efforts of the world's leading nuclear technology nations to develop next generation nuclear energy systems to meet the world's future energy needs.	Argentina, Brazil, Canada, EC (represented by EURATOM), France, Japan, Korea, South Africa, Switzerland, UK, United States
Methane to Markets	Reduce global methane emissions in order to enhance economic growth, strengthen energy security, improve air quality, improve industrial safety, and reduce emissions of greenhouse gases. The Methane to Markets Partnership is an international initiative that advances cost-effective, near-term methane recovery and use as a clean energy source.	Argentina, Australia, Brazil, Canada, China, Colombia, Ecuador, Germany, India, Italy, Japan, Mexico, Nigeria, Poland, Republic of Korea, Russia, Ukraine, UK, United States
ITER	ITER is a joint international research and development project that aims to demonstrate the scientific and technical feasibility of fusion power.	EC (represented by EURATOM), Japan, China, India, Korea, Russia, United States
Global Nuclear Energy Partnership	Develop worldwide consensus on enabling expanded use of economical, carbon-free nuclear energy to meet growing electricity demand. This will use a nuclear fuel cycle that enhances energy security, while promoting non-proliferation. It would achieve its goal by having nations with secure, advanced nuclear capabilities provide fuel services—fresh fuel and recovery of used fuel—to other nations who agree to employ nuclear energy for power generation purposes only. The closed fuel cycle model envisioned by this partnership requires development and deployment of technologies that enable recycling and consumption of long-lived radioactive waste.	Still being formed
Global Gas Flaring Reduction	The GGFR public-private partnership, a World Bank-led initiative, facilitates and supports national efforts to use currently flared gas by promoting effective regulatory frameworks and tackling the constraints on gas utilization, such as insufficient infrastructure and poor access to local and international energy markets, particularly in developing countries.	(Donors: Canada, EU, UK Foreign Commonwealth Office, Norway, United States) (Countries: Algeria (Sonatrach), Angola (Sonangol), Cameroon, Chad, Ecuador, Equatorial Guinea, Indonesia, Kazakhstan, Khanty-Mansiysk (Russian Federation), Nigeria, Norway, United States

TABLE 4-1. *Sampling of Multilateral Energy Technology Initiatives*

PARTNERSHIP	GOAL	MEMBERS
APEC – Energy Working Group	The APEC Energy Working Group (EWG) is a voluntary, regional-based forum operating under the APEC umbrella. EWG helps further APEC goals to facilitate energy trade and investment, and ensure that energy contributes to the economic, social, and environmental enhancement of the APEC community.	Australia, Brunei, Canada, Chile, China, Hong Kong, Indonesia, Japan, Republic of Korea, Malaysia, Mexico, New Zealand, Papua New Guinea, Peru, the Philippines, Russia, Singapore, Chinese Taipei, Thailand, United States, Vietnam
Asia-Pacific Energy Partnership	Public-private partnership to develop and accelerate the deployment of cleaner and more efficient technologies and practices.	Australia, China, India, Japan, South Korea, United States
Security and Prosperity Partnership/ North America Energy Working Group	Under the SPP, the energy goals are to strengthen North America's energy markets by working together, according to our respective legal frameworks, to increase reliable energy supplies for the region's needs and development; by facilitating investment in energy infrastructure, technology improvements, production, and reliable delivery of energy; by enhancing cooperation to identify and utilize best practices, and to streamline and update regulations; by promoting energy efficiency, conservation, and technologies like clean coal.	Canada, Mexico, United States

TABLE 4-2. *Sampling of Regional Multilateral Energy-Related Activities*

International engagement takes many forms, as illustrated in Tables 4-1 and 4-2. The U.S. government engages both producer and consumer countries, as well as the private sector, to maintain open lines of communication and to seek cooperation in overcoming common energy challenges. In general, the U.S. government engages other countries through specially designated bilateral and multilateral energy dialogues, through a series of next-generation energy technology initiatives, and by integrating energy policy considerations into other related bilateral and multilateral fora.

By maintaining frequent and regular contact with major producing and consuming countries through established energy dialogues, the United States has sought to foster greater stability in global energy markets through better communication and coordination. The U.S. military has also played a large role in securing major energy transit choke points throughout the world by maintaining forward deployed positions.

Participation in institutions like the International Energy Agency creates many benefits. It helps to improve data collection and transparency, to coordinate the use of strategic stockpiles during supply disruptions, and to foster joint consideration of energy policy issues that are of particular interest to member countries. Finally, public-private, multilateral partnerships on next-generation energy technologies help to encourage research, development, and deployment of transformative energy technologies.

CONCLUSIONS

U.S. Leadership

American leadership is key to advancing free markets, international stability, and open access to energy and raw material supplies. In order to maintain and reinforce this leadership, the United States must more strongly resist both isolationism and domestic protectionism. The United States must also take the initiative to lock its economic and political principles as deeply as possible into the multilateral system.

America's prosperity rests on reliable access to stable supplies of energy from a global market. It cannot successfully pursue this goal separately from the rest of the world with a unilateral U.S. policy path. Therefore, the United States must adopt a global approach to energy security for its future national prosperity.

This means, in the immediate future, overcoming U.S. disagreements with the EU and some developing countries in global trade negotiations. In the longer term, it means strengthening institutions such as the WTO that enforce the market-based rules of the international system. It also means restoring strong political links with Europe and combating anti-Americanism around the world in more imaginative ways. And, it means doing the utmost to establish stability in the Middle East and to avoid unnecessary confrontation with China.

The U.S. government should press for large emerging consumer countries in the developing world, such as China and India, to be integrated progressively into the international energy security system—into institutions such as the International Energy Agency and the Group of Eight—in order to draw them into a decision-making process based on market principles and to enable closer monitoring of their compliance with international agreements. Irrespective of other policy differences, tbe United States, China, and India share vital common interests as energy importers, and cooperation among them could significantly strengthen the hand of the major consuming nations. It would also help to avert the adoption of divide-and-rule tactics by energy exporters aimed at bidding up prices and securing political objectives.

The United States should also boldly offer credible proposals for reforming international institutions, such as the United Nations and the International Monetary Fund. Multilateral institutions should be strengthened in order to enforce international rules that support not only U.S. interests but those of the rest of the world.

Energy Security

It is incumbent upon both producer and consumer countries to find common ground, or at least to agree to basic principles, for governing the energy sector to ensure a relative degree of stability for all. Tension over energy security has turned energy into a key political preoccupation for governments around the world. The challenge in responding to such short term pressures is that energy policy decisions endure for decades with profound and lasting consequences, yet they are often made to resolve immediate issues with only short-term fixes. Sustainable long-term energy policies can only be developed from a robust and healthy debate over ideas. If a policy is to be effective for an extended period, an informed general public must accept and support not just its tactical aims, but also its strategic goals.

New Policy Tools

Along with a new strategic approach, the emerging energy world requires new policy tools to influence developments. For example, the need to open energy investment markets has largely been left out of WTO and other international trade negotiations, such as for NAFTA. U.S. economic, energy, and security interests, along with those of the rest of the world, will be best served if the United States and its allies work to achieve and maintain an open, multilateral, glohal system to the greatest extent possible.

National Oil Companies

To achieve the expanded production required to meet growing global demand in a timely manner, NOCs should be encouraged to work cooperatively with internationally competitive oil company partners in order to encourage the use of the best technology and to adopt global standards of transparency, accountability, and contract sanctity. The U.S. government should lead a worldwide campaign against resource nationalism and protectionism in resource development.

U.S. Policy Priorities

Measures the United States can take to help achieve the above objectives include:

- An energy policy that recognizes the need for—and actively encourages—long-term investment in production both domestically and abroad.
- Promotion of market energy prices in all countries—many NOCs owe their strong positions to

preferentially low product prices in their home countries. This will become increasingly unsustainable in a carbon-constrained environment.

- Continued openness in the United States to investment by foreign energy companies—especially through the Committee on Foreign Investment in the U.S. process. This is a critical bargaining chip in the U.S. government's efforts to win greater market access for American companies in producing countries.
- A firm stance opposing the carving out of energy investment and energy services from free-trade agreements.

Climate Change

Political consensus and coordinated national and international policies will be needed to facilitate long-term investments and technological advances as part of any attempt to mitigate climate change. Because the world shares a common atmosphere and because energy and other markets are interconnected, responses to climate change should be global.

Corporate Environmental Strategies

Consumers are increasingly aware of the environmental and social impacts of the products they buy. This means that energy companies must pay attention to their images as socially responsible organizations, and offer consumers the opportunity to purchase cleaner, more efficient energy or energy technologies. Companies are increasingly finding ways to turn this attention to sustainability and corporate citizenship to their competitive advantage.

A Global Response

The United States has much to gain by strengthening the international structures that promote maintaining and expanding open global markets and that prevent fragmentation of the world economy. However reluctant we and other countries may be to admit it, energy is a crucial policy area in which the interests of the United States and those of the rest of the world coincide. If the world does not respond creatively to the challenges outlined above, we risk confronting an increasing uncertain future, defined by factors beyond our control or influence.

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Chapter 5

CARBON MANAGEMENT

Abstract

Policies aimed at curbing carbon dioxide (CO_2) emissions will alter the energy mix, increase energy-related costs, and require reductions in demand growth. Effective carbon management will be aided by developing legal and regulatory frameworks to enable carbon capture and sequestration (CCS). As policymakers consider options to reduce CO_2 emissions, they face the challenge of creating a global framework that includes a transparent, predictable, economy-wide cost for carbon emissions.

This chapter considers climate, energy, and emissions concerns by examining the natural carbon cycle in the context of global and U.S. energy sources and uses. Various carbon management options raise new regulatory and policy implications.

An outline of the Carbon Management chapter is as follows:

- Carbon management
- Energy efficiency and demand reduction
- Transportation
- Carbon capture and sequestration.

There is growing concern that the climate is warming and that CO_2 emissions play a role. The most recent report by the Intergovernmental Panel on Climate Change (IPCC) about the physical science basis for climate change states: "Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations."[1] ("Very likely" is greater than 90 percent likelihood, according to the IPCC report.)

Moreover, initiatives in increasing number are emerging, within both the public and private sectors, aimed at reducing carbon emissions. Such a trend highlights the potential for carbon constraint to become a significant feature of future energy strategies. In particular, future carbon constraint could alter the way in which the world uses the fossil fuels that currently provide most of our energy. Since changes in fossil-fuel use could affect diverse lifestyles, economic activity, and energy supply, it is becoming increasingly important to plan for ways to accommodate carbon-constraint policies within any overall energy strategy.

To better understand the range of potential energy futures, the Demand Task Group (see Chapter One) studied in detail five publicly available worldwide energy-demand projections provided by the Energy Information Administration (EIA) and the International Energy Agency (IEA). Economic growth is the primary driver in all these projections. The expected economic growth rates were greater than the current annual rate of 3.1 percent (1980–2000) in all the projections except for the explicitly low-growth EIA Low Economic Growth projection. Four of the projections studied are based on energy-policy assumptions that extend energy policies in effect today. The energy growth rates for these four projections range from 1.5 to 2.5 percent per year, with only the EIA Low Economic Growth projection having an energy growth rate less than the 1980–2000 energy demand growth rate of 1.7 percent per year.

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[1] The Fourth Assessment Report of the Intergovernmental Panel on Climate Change: *Climate Change 2007: The Physical Science Basis.*

Policy assumptions can play a major role in determining the outcome of energy demand projections. The IEA created the Alternative Policy scenario in an attempt to estimate future energy demand, given the major energy policies now under consideration by governments around the world. Currently, there are more than 1,400 energy-related policies either in place or proposed by various countries. The IEA first removed from the list policies already in place. From the remaining policies, it incorporated those that are likely to be implemented in the future. These additional policies included those that increased biofuels use; increased the use of other renewable energy sources; increased the use of nuclear-power generation; created an environment that promoted energy efficiency; encouraged clean-fuel technologies use; and increased the production of domestic fuel supplies.

■ Key Information: Greenhouse Gases

The earth maintains an equilibrium temperature by re-radiating the energy it receives from the sun. So-called "greenhouse gases" trap some of the re-radiated energy. Much of the debate in the past was not directed at the link between global temperature and climate change, but more towards the degree of global warming and the role of man-made greenhouse gases versus the role of natural mechanisms.

Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), fluorinated gases (CFCs), sulfur hexafluoride (SF_6), and nitrous oxide (N_2O), to which human activity contributes atmospheric emissions. Of these, carbon dioxide is the most significant in its potential impact on global temperatures. The degree of warming is linked to the total volume of CO_2 in the atmosphere; since the beginning of the industrial revolution, the amount of CO_2 in the atmosphere has risen by about a third, from around 2,100 billion tons to around 2,750 billion tons. These figures are usually expressed as concentrations of CO_2 in parts per million of the total mass of the atmosphere. The pre-industrial levels of CO_2 were about 280 parts per million and current levels are rising through 380 parts per million. In order to stabilize the concentration of CO_2 and other greenhouse gases in the atmosphere, annual global emissions would have to be brought under control and then made to decline year after year.

Any approach to reducing the growth of the levels of greenhouse gases in the atmosphere must include either reducing the emissions of CO_2 to the atmosphere or enhancing the sinks for CO_2. The former can only be achieved by reducing the amount of fossil fuel burned or by capturing the produced CO_2 and preventing it from reaching the atmosphere. Enhancing carbon sinks can be achieved by increasing the mass of carbon tied up in the biosphere. For example, growing more trees in forests, attempting to induce the growth of algae blooms in oceans, or using more no-till farming methods (increasing carbon uptake in soils) could reduce the levels of CO_2 in the atmosphere.

Other greenhouse gases also can be curtailed. Agricultural practices such as reduced use of fertilizer (reducing nitrous oxide emissions), and collecting and flaring or burning methane from livestock waste, landfills, and coal mines could also play a role in offsetting future greenhouse gas emissions. In addition, reducing leakage of sulfur hexafluoride from utility transmission and distribution equipment, and destroying or avoiding production of fluorinated gases and nitrous oxide could also help control greenhouse gases.

The combined results of the five projections can be summarized as follows:

- Generally the projected world oil share of energy demand is lower in the future, while the natural gas and coal shares are higher.
- The projected nuclear share of world energy demand is lower in all cases except the Alternative Policy Case, where it is about the same as in 2000.
- Global CO_2 emissions were 24 billion metric tons in 2000, growing to a projected range between 34 (Alternative Policy Case) and 51 (High Economic Growth Case) billion metric tons in 2030.
- Projected U.S. energy demand growth rate is higher in the future than in the past in all but the Alternative Policy Case.
- Projected energy shares align in essentially the same way in the United States as in the rest of the world.
- The U.S. rate of growth of CO_2 emissions is projected to increase more slowly in the future than in the past, except in the High Economic Growth Case where emissions may grow more rapidly than in the past.

In light of these projections and the likelihood that some carbon constraint will emerge, and the assumption that the world will want to continue to use fossil fuels for a large fraction of energy requirements in the foreseeable future, it is important that governments and industries plan to accommodate a carbon constraint in their energy strategies. It is unlikely that the continued use of oil, natural gas, and coal, could remain unaffected in a carbon-constrained world.

CARBON MANAGEMENT

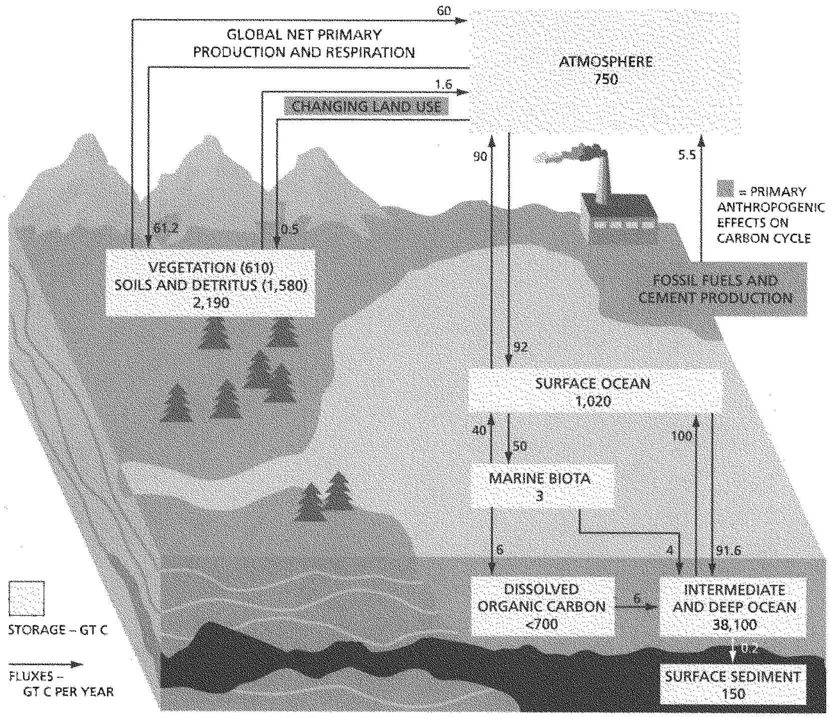
By its nature, climate change is global. The interrelation between energy and other markets requires that an effective response to climate change also, ultimately, be global. Carbon emissions from burning fossil fuels, combined with those from changing land use, augment the large natural flux of carbon between the atmosphere, the land, and the oceans (see Figure 5-1). Rapid mixing in the atmosphere ensures that CO_2 emitted anywhere in the world is quickly distributed about the globe, and since the start of the industrial era, the mass of CO_2 in the world's atmosphere has risen by a third.

Without international cooperation in the coming decades, achieving significant reductions in CO_2 emissions would be elusive, and disparity in national responses would create challenges to the international trade regime as different nations sought to address and prioritize what they saw to be their own particular concerns.

Approaches to reducing CO_2 emissions could include the following elements:

- Energy efficiency and demand reduction
  - Better and more efficient use of energy in all sectors, including transportation, buildings, industrial energy use, and power generation
  - Improved efficiency will need to be translated into reduced energy demand rather than solely into increased performance
- Use of lower-carbon fuels
  - Shift from coal to natural gas
- Use of non-carbon based power ("decarbonization")
  - Nuclear power
  - Wind power
  - Solar power
  - Ocean and geothermal power
- Use of "carbon neutral" energy sources
  - Biomass to augment power generation
  - Biofuels to augment hydrocarbons used for transportation
- Carbon capture and sequestration
  - Preventing the release to the atmosphere of CO_2 generated by the combustion of fossil fuels.

Innovation and deployment of new energy technologies in global energy systems could improve the potential for significant reductions in CO_2 emissions while maintaining the desired level of economic activity. This would require substantial private- and public-sector investments in research, development, demonstration, and deployment. The most cost-effective CO_2 policies would involve broad, technology neutral, market-based mechanisms to create incentives for the private sector to undertake these technology changes.



Source: OSTP NanoEnergy Brief, 10 August 2005, available at www.er.doe.gov/bes/presentations/OSTP_NanoEnergyBrief_10AUG05.pdf (based on D. Schimel, D. Alves, I. Enting, M. Heimann, F. Joos, D. Raynaud, and T. Wigley, 1996: "CO_2 and the Carbon Cycle").

FIGURE 5-1. *The Global Carbon Cycle, with 1990s Carbon Fluxes in Gigatons of Carbon (GT C) per Year*

The Continued Use of Domestic Energy Resources under Carbon Constraint

Currently, fossil fuels (oil, natural gas, and coal) provide more than 80 percent of the world's energy needs. In terms of global CO_2 emissions from fossil fuels, oil accounts for 39 percent of these emissions and natural gas for 20 percent, while coal accounts for the remaining 41 percent.[2] Within the United States, fossil fuels similarly provide more than 80 percent of the nation's energy needs, as shown in Figure 5-2, which details the distribution both of the sources and the uses of the national energy budget in units of 10^{15} Btu (quads) (where 1 quad = 293 billion kilowatt-hours). The figure reveals both the degree of dependence on fossil fuels and the amount of energy lost, which in turn provides some measure of the potential scope for efficiency improvements.

Absent societal and market responses to climate change, oil, natural gas, and coal would continue to

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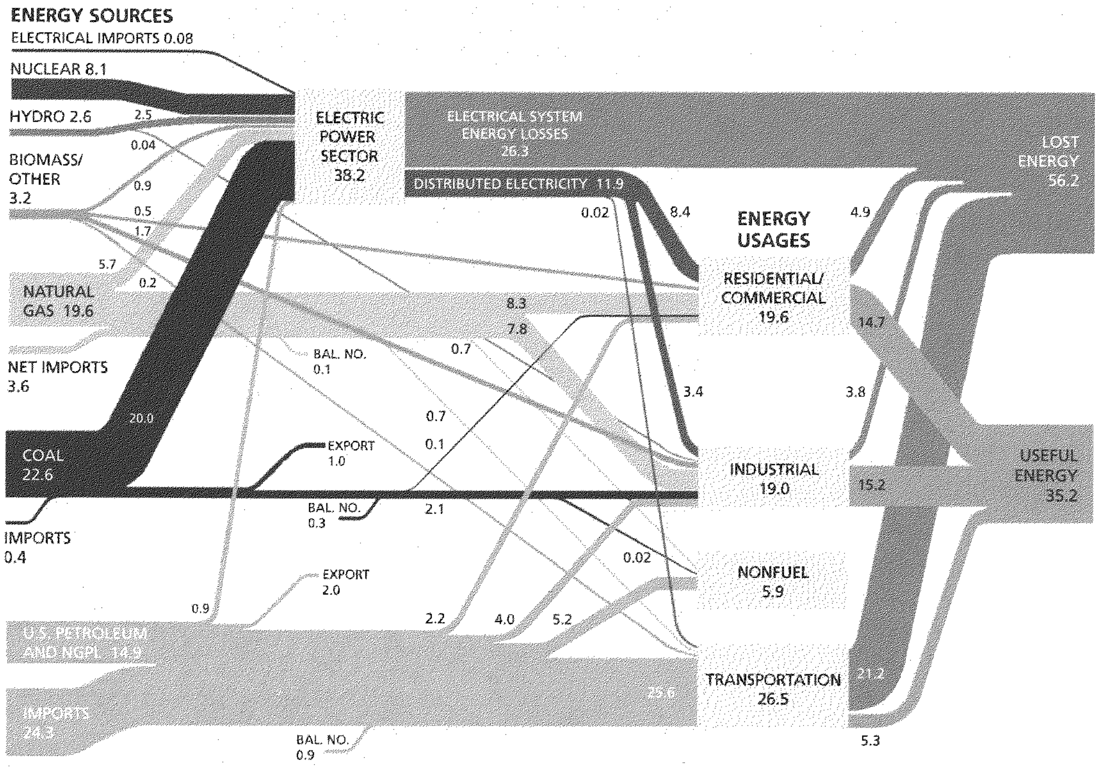
[2] International Energy Agency, *World Energy Outlook 2006.*



Source: Lawrence Livermore National Laboratory, 2004.

FIGURE 5-2. *U.S. Energy Sources and Uses in 2002 (Quadrillion Btu per Year)*

play a major role in energy supply over the next three decades and beyond. In particular, because of its high energy density, and the convenience of using a liquid fuel, petroleum would continue to dominate transportation. Conventional oil, heavy oils, and, to a lesser extent, biofuels and liquid fuels derived from natural gas and coal would ensure continuity of supply for transportation at relatively low cost. At the same time, heat and power would be dominated by coal and natural gas from domestic resources.

The question arises: What happens to this projection if there is significant constraint on CO_2 emissions? Given that most energy-related CO_2 emissions come from fossil fuels, the use of these resources cannot remain unaffected in a carbon-constrained world. A combination of improved efficiency, demand reduction, decarbonization, and CCS would be needed to reduce emissions. CCS would strongly determine the extent to which we could continue to use a variety of fossil fuels, and in particular it would enable the continued use of the large domestic U.S. coal reserves while still reducing CO_2 emissions. Similarly, incorporating CCS, China and India could reduce their CO_2 emissions while continuing to use their own substantial coal reserves.

ENERGY EFFICIENCY AND DEMAND REDUCTION ✦

Improving the efficiency of energy use within the industrial, commercial, domestic, and transportation sectors has the potential to reduce energy use without reducing economic activity, and to reduce the associated CO_2 emissions. However, to achieve this, incentives would be needed to encourage investments in higher-efficiency capital and to encourage using newly gained efficiency to actually reduce demand. Key to stimulating long-term investment by the private sector in more energy-efficient capital would be a steady, predictable, long-term increase in the cost of CO_2 emissions. This would be enhanced by government incentives to economically retire older, high-CO_2 emitting plants as well as to invest in newer, low-emissions capital. Incentives in the building sector, both commercial and domestic, would be needed to encourage the use of higher-efficiency construction techniques and efficient cooling and heating systems, which often come at a higher initial cost with a long "pay-back" period.

TRANSPORTATION

While CCS can address CO_2 emissions from coal and the extra emissions associated with producing unconventional oil, it cannot address the tail-pipe emissions produced when using hydrocarbon fuels for transportation. If we wished, in a carbon-constrained world, to continue significant use of gasoline and diesel as transportation fuels, and at the same time to reduce CO_2 emissions, then other approaches would be needed. The appropriate measures to achieve such reductions would focus largely on a combination of improved engine efficiency and on regulatory mechanisms to reduce demand.

There is potential to almost double the efficiency of existing gasoline- and diesel-powered vehicles. And there are technologies to augment internal-combustion engines in cars using electric hybrids and plug-in electric hybrids, which are already available. So long as the centralized electricity generating plants control CO_2 emissions, then the electrification of cars helps reduce overall CO_2 emissions as well as reduce the requirements for oil imports. Examples of such solutions include integrated coal-fired power with CCS or alternative low-carbon electricity sources such as nuclear, wind, or other renewables.

However, technical efficiency improvements may not, by themselves, lead to a reduction in the demand for hydrocarbon fuels. Over the past two decades, light-duty vehicle efficiency improvements in the United States have been countered by increased miles driven and heavier, higher-performance vehicles. Active policies to reduce demand for transportation fuel would be an important element in any portfolio of strategies to reduce CO_2 emission in a carbon-constrained world. Demand reduction could be achieved by combining approaches that reflect the following considerations:

- Reducing carbon emissions from transportation would have key importance in a carbon-constrained world.
- Public education, particularly of the next generation of consumers, would play an important role in long-term strategies to reduce demand.
- Improved engine efficiency enables demand reduction, especially if accompanied by other mechanisms to reduce demand.

- Increasing fuel price is unlikely to be sufficient by itself. A combination of increased price and regulation would probably be necessary to reduce demand effectively.
- Government incentives to increase the use of public transport would help reduce demand for transportation fuel.
- Congestion charges and high-occupancy vehicle (HOV) systems would further help reduce fuel demand.
- Government incentives to retire older, less-efficient vehicles would help reduce fuel demand, and programs to audit the energy efficiency of the existing fleet would be an effective complement to such incentives.

CARBON CAPTURE AND SEQUESTRATION ✦

In a carbon-constrained world, CCS would allow us to sustain many of the benefits of using hydrocarbons. Even where the CO_2 generated by burning hydrocarbons cannot be captured easily, as with using oil for transportation, sequestering CO_2 from other sources (such as coal-fired power stations) can help create—to some degree—the margin needed to allow for the volumes of CO_2 that escape capture. Fossil fuels are likely to remain an important part of the energy mix, because of the continuing competitive (direct) cost of hydrocarbons, and the huge investment already made in infrastructure to deliver them. Therefore, the combination of fossil fuel use with CCS is likely to be emphasized as a strong complement to strategies involving alternative, non-hydrocarbon, energy-supply sources, and to measures designed to encourage more efficient energy use. Here we compile key questions about the potential for CCS technology.

What is the Contribution of CCS to Maintaining Energy Supply from Fossil Fuels?

In a carbon-constrained world, CCS would play a key role in allowing the continued use of coal and the growing use of unconventional oil. By providing a means for dealing with a significant fraction of the CO_2 emissions from fossil fuels, CCS would allow us to retain fuel diversity for many decades. CCS would be implemented largely in association with burning coal, which, worldwide, now accounts for 41 percent of all CO_2 emissions from fossil fuels. At the same time, chemical plants and centralized power generation using natural gas or oil could also incorporate CCS.

The growing need to provide transportation will increase the pressure to move towards other fossil sources for liquid fuels, such as unconventional oil (heavy oil, shale oil, tar sands) and coal-to-liquids (CTL) technologies. Since exploiting these resources comes with a significantly heavier CO_2 burden than with conventional oil and natural gas, then in a carbon-constrained world, CCS would become increasingly important. CCS can be directly applied to the extraction of unconventional oil and to the CTL process, and has the potential to mitigate the extra CO_2 burden beyond that from using these fuels for transportation. This facilitates their use under carbon constraint.

CCS also has application to disposal of petroleum coke (petcoke), which is the "bottom of the barrel" residue produced by the world's refineries. Petcoke is similar to coal as a fuel, but petcoke's generally higher sulfur level can be a significant challenge to its use for power generation. However, gasification, along with CCS, makes it possible to burn polluting fuels like petcoke because removing pollutants from a high-pressure gas stream is much cheaper than from a stack. Petcoke-fueled power, combined with CCS, has the potential to transform a costly problem into a profitable technology.

What is the Level of Readiness for Large Scale CCS?

The technologies for capturing CO_2 from pre- and post-combustion gas streams are available. However, their costs are somewhat uncertain and constraints remain on the levels of oxygen, particulates, and sulfur oxides for effective extraction using conventional amine solvents. Current capture technologies also prefer steady-state conditions that do not always prevail in the power-generation industry. Similar concerns apply to the more sophisticated pre-combustion capture. However, broadly speaking, the capture technologies exist and are not critically dependent on new technological breakthroughs. The same is true for CO_2 sequestration technologies; the oil industry has extensive experience with pumping liquids into subsurface formations and evaluating the security of these formations for storage. Currently, several pilot projects have successfully demonstrated sequestration of CO_2 in volumes amounting to millions of tons.

Still missing is the demonstration of fully integrated CCS at commercial scale, along with an established legal and regulatory environment that will enable and encourage CCS. There is, we believe, a strongly growing need within the United States to implement full-scale integration of power generation and CCS. Elsewhere, there are efforts to create just such integration. China, in particular, with funding from the European Union, plans a full-scale plant with CCS within the next five years. The United States should not delay such implementation while awaiting further research. We recommend that the United States achieve the necessary refinements in the largely existing technologies by accelerating full-scale implementation. Further, the United States should share its experience with other nations.

Does the Capacity for Underground Storage Exist?

It is very likely that there is ample storage space in subsurface formations to store enough CO_2 to substantially alleviate atmospheric emissions. What is less well known is the distribution and availability of these storage resources. While exhausted oil and natural gas reservoirs will provide room for considerable amounts of CO_2, it will probably be necessary to also use deep saline formations, depending, for example, on the siting requirements for power stations with CCS. Subsurface storage space will become a resource, with its own supply curve, and we recommend that the United States extend activities by the Carbon Sequestration Regional Partnerships and conduct, at a federal level, a full survey of the nation's potential sequestration sites. A preliminary map of potential U.S. storage sites is shown in Figure 5-3. Other nations should be encouraged to do the same.

What is the Cost of CCS Compared to Other Approaches to Carbon Mitigation?

CCS represents a competitive way to address a substantial fraction of the potential need for carbon mitigation; the IPCC Special Report on Carbon Dioxide Capture and Storage points out that including CCS in a mitigation portfolio could achieve suitable stabilization of CO_2 concentrations in the atmosphere at a lower cost than otherwise.[3] The IPCC report observes: "Models indicate that CCS systems will be competitive with other large-scale mitigation options such as nuclear power and renewable energy technologies. These studies show that including CCS in a mitigation portfolio could reduce the cost of stabilizing CO_2 concentrations by 30 percent or more. One aspect of the cost competitiveness of CCS technologies is that they are compatible with most current energy infrastructures."

Current estimates for the cost of CCS implementation on coal and natural gas fired power plants are about \$40/ton of CO_2. This includes the cost to capture the CO_2, compress it to supercritical (liquid) form, and inject it in the subsurface for sequestration. To put this cost in perspective, \$40/ton of CO_2 equates to between 2 and 4 cents per kilowatt-hour depending on the fuel source, with gas at the lower end of the range and coal at the upper end.

Efforts to reduce CCS costs would focus on capture technology, which today accounts for about half the cost. There is considerable scope for improving the current capture technologies, and for implementing new ones. Nonetheless, research in these areas should parallel implementing current technologies, and should not serve as a reason to delay a rapid start on full-scale CCS.

What is the Role of CO_2-Based Enhanced Oil Recovery (CO_2-EOR) in CCS?

Large volumes of naturally occurring CO_2 obtained from underground deposits are currently used by the oil industry to enhance the recovery of oil from mature reservoirs.[4,5] This CO_2-EOR is currently conducted without regard to storing the CO_2 "downhole." However, with relative ease present technology could

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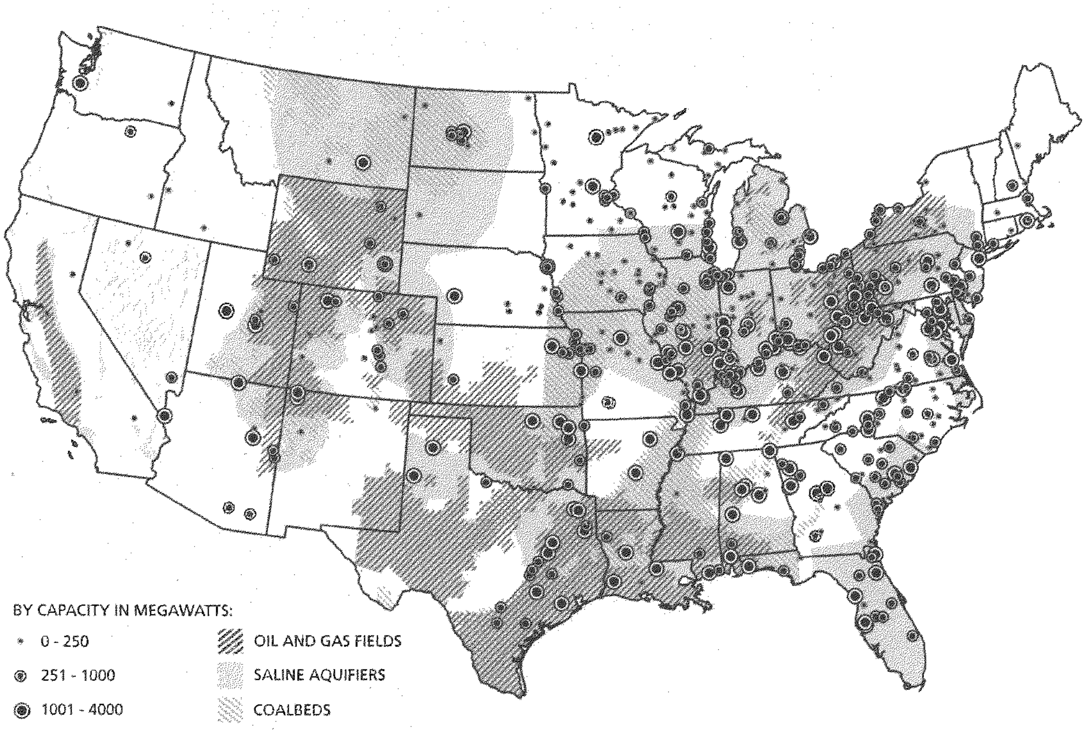
[3] Intergovernmental Panel on Climate Change, *IPCC Special Report on Carbon Dioxide Capture and Storage,* 2005, Interlachen, http://www.ipcc.ch/.

[4] Melzer LS (ed.), "CO2 Sourcing for Enhanced Oil Recovery," The University of Texas of the Permian Basin's Center for Energy and Economic Diversification Short Course #13 on Carbon Dioxide Flooding, Presented at the Annual CO2 Flooding Conference, Midland, Texas, December 6, 2004.

[5] Bliss K, "Final Report for DOE Award No. DE-FC26-03NT41994, Admendment No. A000," report submitted by the Interstate Oil and Gas Compact Commission, Oklahoma City, OK (January 24, 2005): 31, available at http://www.iogcc.state.ok.us/PDFS/CarbonCaptureandStorageReportandSummary.pdf.



TOTAL CAPACITY: ≈ 330 GIGAWATTS

Note: For further information on and maps of carbon sources and potential sequestration sites, see www.natcarb.org.

FIGURE 5-3. *U.S. Coal-Fired Power Plants (2000) and Potential Sequestration Sites*

be modified to emphasize such storage. In a carbon-constrained world, we could also expect rising pressure to use anthropogenic CO_2 to drive this recovery enhancement, which would lead to a net reduction in atmospheric CO_2. While the likely extent of CO_2-EOR provides a relatively small fraction of the capacity needed for CO_2 sequestration, it does offer a strong technology bridge to carbon-sequestration technologies and should be encouraged as an important element of a CCS strategy. Government incentives for CO_2 storage in association with CO_2-EOR, and new arrangements for developing suitable infrastructure for commercial use of anthropogenic CO_2 for EOR with storage, could help CO_2-EOR for storage succeed, particularly as CO_2 becomes increasingly available (and increasingly cheap) under a wide-scale adoption of CCS.

Regulation

The technological hurdles to effectively implementing CCS are surmountable. However, the regulatory framework within which CCS is deployed will play an important role in determining CCS's future. The legislative framework within whicb CCS is conducted will have a major impact on how rapidly the technology is implemented. And legislation will ultimately determine whether CCS can effectively mitigate carbon emissions and facilitate using future hydrocarbon supplies.

During a 2006 G8 forum on carbon sequestration,[6] more than 120 participants from 15 nations identified 5 critical areas of regulation that need to be resolved in order to facilitate the near-term deployment of CCS:

- Ownership and liability of CO_2 at every step along the "value chain"
- Regulatory treatment of CO_2 and other gases in the CO_2 stream
- Monitoring, verification, and remediation
- Property rights and intellectual property
- Jurisdictional and trans-boundary issues.

Moreover, the roles of federal and state governments, regarding which authority is responsible for which regulation or permitting process, need clarification. Such clarification will help attract commercial players into the carbon capture and storage market. Participants of the G8 forum felt that "progress cannot be made on near term opportunities if this issue is not resolved."

CCS Conclusion

In summary, CCS would greatly facilitate tbe sustained use of oil, natural gas, and coal to meet U.S. energy demands in a carbon-constrained world. Moreover, it would reduce the pace at which we would otherwise need to develop and employ alternative energy sources. CCS is viable and its introduction is not limited by any need for significant technological breakthroughs.

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[6] G8 International Energy Agency (IEA) & Carbon Sequestration Leadership Forum (CSLF) First Workshop on Near Term Opportunities, held 22–23 August 2006, San Francisco.

Chapter 6
RECOMMENDATIONS

Abstract

The NPC study participants developed recommendations in the following five strategic areas. Study participants believe that implementing these five strategies will enable industry and government to more adequately prepare for the hard energy truths facing the United States and the world.

The NPC makes the following policy recommendations by strategy.

- Moderate demand by increasing energy efficiency
- Expand and diversify U.S. energy supply
- Strengthen global and U.S. energy security
- Reinforce capabilities to meet new challenges
- Address carbon constraints

■ Moderate Demand by Increasing Energy Efficiency

Improve Vehicle Fuel Economy ✦

The NPC makes the following recommendations to increase vehicle fuel economy:

- Improve car and light-truck fuel economy standards at the maximum rate possible by applying economic, available technology.
  - Update the standards on a regular basis.
  - Avoid further erosion of fuel economy standards resulting from increased sales of light trucks, or, alternatively, adjust light-truck standards to reflect changes in relative light-truck and car market shares.

Potential Effect: 3-5 million barrels of oil per day in the United States from the increased base in 2030.

Reduce Energy Consumption in the Residential and Commercial Sectors ✦

Building Energy Codes
Appliance and Equipment Standards

The NPC makes the following recommendations to improve efficiency in the residential and commercial sectors:

- Encourage states to implement and enforce more aggressive energy efficiency building codes, updated on a regular basis.
- Establish appliance standards for new products.
- Update federal appliance standards on a regular basis.

Potential Effect: 7-9 quadrillion Btu per year by 2030 in the United States, including 2-3 quadrillion Btu per year of natural gas (5-8 billion cubic feet per day), 4-5 quadrillion Btu per year of coal, and ~1 quadrillion Btu per year (0.5 million barrels per day) of oil.

Increase Industrial Sector Efficiency ◆

The NPC makes the following recommendations to improve efficiency in the industrial sector:

- The Department of Energy should conduct and promote research, development, demonstration, and deployment of industrial energy efficiency technologies and best practices.
- The research and development tax credit should be permanently extended to spur private research and development investments.

Potential Effect: 4-7 quadrillion Btu per year by 2030 in the United States, about equal parts coal, gas, and oil.

■ Expand and Diversify U.S. Energy Supply

Understanding the Range of Production Forecasts

Recommendations for improved understanding of forecasts and data are discussed specifically in the section "Improve the Quality of Energy Data and Information" later in this chapter.

Reduce Declines in U.S. Conventional Oil and Natural Gas Production ◆

The NPC makes the following recommendations to promote enhanced oil recovery (EOR) from existing reservoirs:

- Support regulatory streamlining and research and development programs for marginal wells.
- Expedite permitting of EOR projects, pipelines, and associated infrastructure.

Potential Effect: An additional 90 to 200 billion barrels of recoverable oil in the United States alone, which could help slow the current decline in production

Increase Access for New Energy Development ◆

The NPC makes the following recommendations to expand access to the most favorable U.S. oil and natural gas basins:

- Conduct national and regional basin-oriented resource and market assessments to identify opportunities for increasing oil and natural gas supply.
- Use technology and operational advancements to allow environmentally responsible development of high potential onshore and offshore areas currently restricted by moratoria or access limitations.

Potential Effect: Material increases to current production within 5 to 10 years from currently inaccessible areas could approach 40 billion barrels of oil and 250 trillion cubic feet of natural gas with current technology.

The NPC makes the following recommendations to increase unconventional oil and natural gas production:

- Accelerate U.S. oil shale and oil sands research and development and leasing.
- Accelerate U.S. unconventional natural gas leasing and development.

Potential Effect: Double U.S. unconventional natural gas production to more than 10 billion cubic feet per day, increasing total U.S. natural gas production by about 10 percent.

Diversify Long-Term Energy Production ◆

Accelerate the Development of Energy from Biomass

The NPC makes the following recommendations to accelerate development of biomass energy sources at large commercial scale:

- Support research into second-generation biofuel crops that have lower input requirements or are suited to more marginal lands.
- Promote agricultural policies that enhance global production of both food crops and biomass for fuel.
- Support policies that promote the development of the infrastructure for harvesting, storing, and transporting energy crops, and facilitate the integration of biofuels into the national transportation fuel supply.

Potential Effect: Increase U.S. production by up to 4 million barrels per day of oil-equivalent liquids[1]

Enable the Long-Term Environmental Viability of Coal for Power, Fuel, and Feedstock

Recommendations for maintaining coal's long-term viability are discussed specifically in the section "Address Carbon Constraints" later in this chapter.

Expand Domestic Nuclear Capability

The NPC makes the following recommendations to expand the domestic technical and industrial capabilities of the nuclear energy/power industry:

- Implement the recommendation by the National Commission on Energy Policy[2] to provide $2 billion over ten years from federal energy research, development, demonstration, and deployment budgets for demonstration of one to two new advanced nuclear facilities.
- Fulfill existing federal commitments on nuclear waste management.

Potential Effect: Reestablish U.S. leadership capability. Maintaining a viable nuclear energy option will increase policy choices in future carbon-constrained circumstances.

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[1] The "Billion Ton Study" – *Biomass as a Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*, USDA and USDOE, April 2005, available at http://www.osti.gov/bridge

[2] See www.energycommission.org/files/contentFiles/report_noninteractive_44566feaabc5d.pdf, page IV

Strengthen Global and U.S. Energy Security ◆

The NPC makes the following recommendations to promote global and U.S. energy security:

- Integrate energy policy into trade, economic, environmental, security, and foreign policies by having the Department of Energy share an equal role with the Departments of Defense, State, Treasury, and Commerce on policy issues relating to energy and energy security.
- Continue to develop the international energy marketplace by expanding the energy dialogue with major consuming and producing nations, including China, India, Canada, Mexico, Russia, and Saudi Arabia.
- Promote an effective global energy marketplace by sustaining and intensifying efforts to encourage global adoption of transparent, market-based approaches to energy through multilateral and international institutions—including the World Trade Organization, G8, Asia-Pacific Economic Cooperation (APEC), IEA, International Energy Forum, and the Joint Oil Data Initiative (JODI).
- Assist and encourage global adoption of energy efficiency technologies through technology transfer programs and lend-lease arrangements.

Potential Effect: Restricted resource access and curtailed production could put potential 2030 global liquid (25-35+ million barrels per day) and gas (150-200+ billion cubic feet per day) incremental growth at risk.

Reinforce Capabilities to Meet New Challenges

Develop a Comprehensive Forecast of U.S. Infrastructure Requirements ◆

The NPC makes the following recommendations to improve understanding of infrastructure needs to meet future U.S. energy system growth:

- The Department of Energy (DOE) should develop an integrated study of the energy infrastructure needs to 2030.
- The EIA should incorporate infrastructure-related data into its energy information collection system.

Rebuild U.S. Science and Engineering Capabilities ✦

The NPC makes the following recommendation to enhance U.S. science and technical education programs:

- Provide support to those seeking engineering and other technical degrees, both undergraduate and graduate, by increasing scholarships and research funding at universities and support for technical schools.

The NPC makes the following recommendation to make it easier for retirees to continue working as consultants, teachers, and coaches:

- Modify the U.S. tax code and retirement plan regulations to allow part-time work after retirement without penalty.

The NPC makes the following recommendation to increase the supply of trained energy professionals in the United States:

- Increase student and immigration quotas for trained professionals in energy and technical fields.

Create Research and Development Opportunities ✦

The NPC makes the following recommendations to expand research and development opportunities to support long-term study goals:

- Review the current DOE research and development portfolio to refocus spending on innovative, applied research in areas such as EOR, unconventional oil and natural gas, biofuels, nuclear energy, coal-to-fuels, and CCS.
- Maintain a fundamental research budget in the DOE Office of Science to support novel technologies.
- Focus and enhance research in the U.S. universities and National Laboratories.
- Encourage DOE, Department of Defense, and industry cooperation in innovative areas of development, such as advanced materials and metocean information and analyses.

Improve the Quality of Energy Data and Information ✦

The NPC makes the following recommendations to enhance the quality of energy data and information:

- Expand data collected by EIA and IEA to provide additional sources of production and consumption data for inclusion in annually prepared public domain energy outlooks.
- Expand funding for data collection and analysis of energy transportation systems to enable informed infrastructure decisions.

The NPC makes the following recommendations to update publicly available global endowment and resource estimates:

- The USGS should conduct a comprehensive geological assessment of U.S. and global oil and natural gas endowment and recoverable resources.
  - Incorporate wider participation of industry and international experts and current data.
- The USGS should conduct a new, comprehensive survey of U.S. and global recoverable coal resources and reserves using common analysis and reporting methodologies.
- The U.S. Departments of Energy and Agriculture should conduct a global biomass resource assessment.

Potential Effect: Timely and better informed policy decisions based on shared understanding of critical resource data

■ Address Carbon Constraints

Enable Carbon Capture and Sequestration ✦

The NPC makes the following recommendations to enable long-term environmental viability of coal for both power and fuel:

- Establish a legal and regulatory framework that is conducive to CCS.
  - Provide regulatory clarity for land use and liability policies.
  - Provide access to federal lands for storage.

- Enable full scale CCS and clean coal technology demonstration.
  - Organize efforts between the power and oil/natural gas industries.
- Undertake a national CO_2 sequestration capacity assessment.
  - Build on the existing efforts being undertaken by the DOE Regional Partnerships.
  - Encourage global application.
- Continue federal research and development support for advanced coal-to-fuel technologies.

Potential Effect: Maintaining coal's projected 30 percent contribution (54 quadrillion Btu per year in 2005) to the future U.S. energy mix, including potential coal-to-liquids production, even in carbon-constrained circumstances.

As policymakers consider actions to reduce CO_2 emissions, the NPC recommends including:

- An effective global framework for carbon management incorporating all major emitters of CO_2 and focusing particularly on opportunities for U.S.–China cooperation.
- A U.S. mechanism for setting an effective cost for emitting CO_2 that is:
  - Economy-wide, market-based, visible, transparent, applicable to all fuels.
  - Predictable over the long term for a stable investment climate.
- A credit for CO_2 used in enhanced oil and natural gas recovery.

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Chapter 7
METHODOLOGY

Abstract

The global oil and gas study prepared by the National Petroleum Council (NPC) is unique in scope and participation. The complexity and scale of integrated energy markets, and the long lead-times necessary to make material changes required a study that took a long-term, comprehensive view of supply, demand, infrastructure, technology, and geopolitics. To achieve this, more than 350 expert participants from diverse backgrounds and organizations joined in a comprehensive work effort based on sound data and science. The effort included analysis of multiple public and aggregated proprietary energy outlooks, and required subgroups to address themes as diverse as deepwater exploration, renewable energy, transportation efficiency, and human resources. In addition, more than 1,000 persons and groups actively involved with energy issues provided feedback through a formal outreach program. The study includes core strategies and key recommendations for policymakers. When developing findings and recommendations, the study leadership sought to balance economic, security, and environmental perspectives.

This chapter describes how the study was organized and conducted. It describes the participants and expert task groups, identifies cross-cutting topics that emerged, details the data streams used for analyses, and explains how a data warehouse was created. An important feature of the report is a survey of 24 parallel studies that were recently published. The full report will be distributed broadly to government and public audiences.

The outline for this chapter is as follows:

- Guiding Principles
- Study Organization
  - Task Groups
  - Cross-Cutting Groups
  - Integration Team
- Information Management
  - An Analytical Approach
  - Storing Information—The Data Warehouse
  - Public Data and Information
  - Proprietary Data and Information
  - Parallel Studies
- Summary.

This report originated in late 2005, when Secretary of Energy Samuel Bodman requested that the NPC undertake a study on the ability of global oil and natural gas supply to keep pace with growing world demand. The Secretary suggested three questions that might be considered:

- What does the future hold for global oil and natural gas supply?

- Can incremental oil and natural gas supplies be brought on-line, on-time, and at a reasonable price to meet future demand without jeopardizing economic growth?
- What oil and gas supply strategies and/or demand-side strategies does the Council recommend the U.S. pursue to ensure greater economic stability and prosperity?

Accepting the Secretary's request, the NPC formed the Committee on Global Oil and Gas with Lee Raymond, former Chairman and Chief Executive Officer of Exxon Mobil Corporation, as its Chair. Clay Sell, the Deputy Secretary of Energy, was designated by Secretary Bodman to serve as the study's Government Cochair. From the 54 NPC members of the Committee on Global Oil and Gas, Mr. Raymond appointed four as Vice Chairs for specific areas of the study. These six served as an "Executive Committee" to oversee the study process. A Coordinating Subcommittee (CSC) was created to guide and focus this ambitious undertaking. Additionally, four task groups and 36 subgroups assisted in the conduct of the study. The study organization is described more fully in the Preface and is outlined in Figure 7-1. The rosters of all the study groups are in Appendix B.

The CSC included members from government, industry and non-governmental organizations to provide a wide range of skills and viewpoints, as shown in Figure 7-2.

GUIDING PRINCIPLES

The CSC's first task was to set the study's boundaries and guiding principles. First, the study leadership recognized that this undertaking would be incomplete without examining all the dimensions of the energy debate including alternative energy sources. Second, the CSC decided the study would not create a new forecast of demand, supply, or price offering yet another perspective on the uncertain energy outlook. Rather, the study would analyze existing projections and outlooks to identify underlying assumptions, understand why they differ, and thereby identify critical factors governing the future of oil and gas to 2030. Third, the CSC decided to consider and balance other points of view, including economic, environmental, and security goals. These

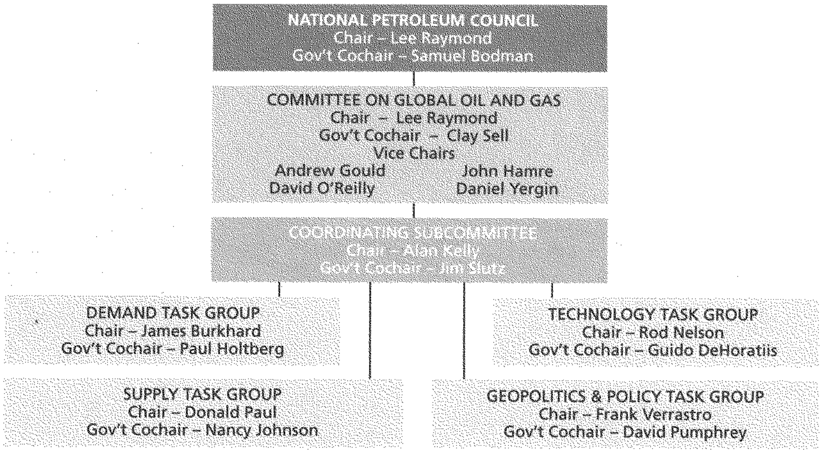

NATIONAL PETROLEUM COUNCIL
Chair – Lee Raymond
Gov't Cochair – Samuel Bodman
COMMITTEE ON GLOBAL OIL AND GAS
Chair – Lee Raymond
Gov't Cochair – Clay Sell
Vice Chairs
Andrew Gould
John Hamre
David O'Reilly
Daniel Yergin
COORDINATING SUBCOMMITTEE
Chair – Alan Kelly
Gov't Cochair – Jim Slutz
DEMAND TASK GROUP
Chair – James Burkhard
Gov't Cochair – Paul Holtberg
TECHNOLOGY TASK GROUP
Chair – Rod Nelson
Gov't Cochair – Guido DeHoratiis
SUPPLY TASK GROUP
Chair – Donald Paul
Gov't Cochair – Nancy Johnson
GEOPOLITICS & POLICY TASK GROUP
Chair – Frank Verrastro
Gov't Cochair – David Pumphrey

FIGURE 7-1. *Study Organization*

FIGURE 7-2. Diverse Leadership

three decisions enabled the NPC to create an original study with broad perspective.

The following guiding principles were pursued throughout the study:

- This is not another energy forecast of demand, supply, or price.
- Experts will gather and analyze public and aggregated proprietary data.
- Study teams will solicit input from a broad range of interested parties.
- Analyses will emphasize long-term conditions, not near-term volatility.
- Recommendations will be supported by sound data and science.
- Participants will comply fully with antitrust laws and regulations.

The study was designed in full compliance with both the letter and the spirit of all applicable laws and regulations, including but not limited to antitrust laws and the Federal Advisory Committee Act, in mind. Specifically, an independent accounting firm aggregated and removed all identifying information from all proprietary projection data provided by companies and consultants. More generally, the study was conducted in strict compliance with comprehensive antitrust guidelines governing all participants' conduct throughout all stages of the study, including data analysis, outreach sessions, meetings among the various participants, and preparation of this report. These guidelines ensured that no individually identifiable sensitive competitive information was exchanged during the study and effectively precluded any opportunities for anticompetitive agreement. An Antitrust Advisory Subgroup provided guidance to the study.

The study leadership was committed to receiving views and information from a broad range of interested parties, and focused outreach efforts to countries and organizations involved with energy. The effort included:

- More than 350 participants from diverse backgrounds
- Dialogue with more than 1,000 persons and groups with energy interests
- Department of Energy support to approach 19 key countries for information.

Figure 7-3 illustrates the diverse backgrounds of study participants.

The Coordinating Subcommittee defined a timeline for the entire study, which continued for more than 18 months. To ensure real-time communications, and to assess progress, representatives from the CSC, including Department of Energy and legal advisors, created a study website for posting all deliverables, analyses and status updates. Monthly meetings were scheduled for the CSC and Task Groups, supplemented by weekly teleconferences to review work products and commitments. The NPC Executive Committee participated in periodic reviews to receive updates and provide guidance. Finally, the CSC leadership provided regular status reports to all participants.

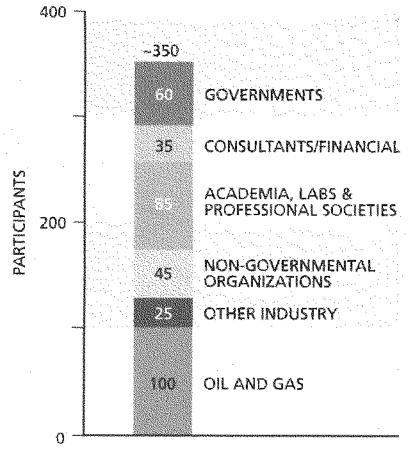


FIGURE 7-3. *Diverse Backgrounds of Participants*

STUDY ORGANIZATION

Task Groups

As the scope of the study evolved, four core groups of subject matter experts were assembled into specialized Task Groups: Demand, Supply, Technology, and Geopolitics & Policy. These Task Groups became the focus of the study's research and analytical efforts. The CSC guided the Task Groups to respond to a series of comprehensive framing questions through an extensive analysis of available reports and publications. The teams developed a broad range of integrated summary observations and findings, which eventually underpinned the agreed strategies and recommendations in the report. Supporting the Task Groups were numerous cross-cutting subgroups that examined specific topics to complement key subject areas. The membership of each of the cross-cutting groups is also found in Appendix B and a simplified diagram of Task Group interrelationships is shown in Figure 7-4.

While the four Task Groups were charged with specific, separate project objectives, the teams' efforts were fully aligned and integrated as depicted in Figure 7-4. Individual subject matter experts selected for this study were not only experienced at interpreting and analyzing Task Group-specific information, but also had sufficient breadth of knowledge to communicate and share information across the team boundaries. Extensively detailed topic papers prepared by each Task Group are also made available to supplement this report. A listing of the topic papers can be found in Appendix E.

Demand Task Group

The Demand Task Group analyzed the range of projections for world energy demand to 2030, key "drivers" underlying the demand projections such as economic activity and demographics, and the relationship of historical performance to future projections. The group analyzed the potential effect of energy efficiency measures on demand, ways that environmental concerns might alter the energy mix, and how fuel-use patterns might evolve. The group

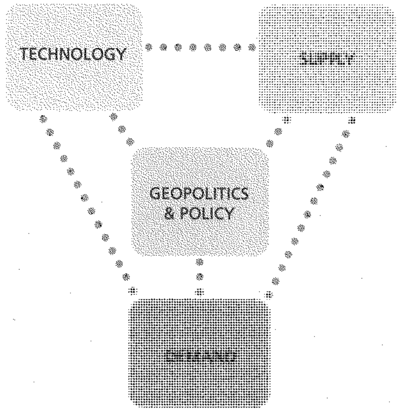


FIGURE 7-4. *Task Group Interrelationships*

also worked with the Supply Task Group to address critical infrastructure implications posed by differing fuel use.

The Demand Task Group organized its activities into six subgroups: Demand Data Evaluation, Electric Generation Efficiency, Coal Impact, Industrial Efficiency, Cultural/Social/Economic Trends, and Residential/Commercial Efficiency. The subgroups prepared topic papers that summarized input, analyses, and findings. After identifying the most significant issues, the group developed potential demand moderation strategies as a step toward formulating recommendations. The Demand Task Group's analyses and conclusions are summarized in Chapter One of this report.

Supply Task Group

To guide its assessment of the global supply of energy, the Supply Task Group considered how the energy supply/capacity mix may change and evolve over the next 25 years. The group considered a wide variety of outlooks for future oil and gas supply/capacity, and assessed the key factors that drive supply changes. The group asked what additional data could help reduce the uncertainty associated with the global energy endowment and the timing for converting it into production capacity—resource endowment, infrastructure, geopolitics, technology progress/utilization, for example. The group examined how coal might fit into the future energy mix, weighing ample supply against environmental consequences and the likely costs to address carbon constraints. Significantly, the group examined the range of outlooks for non-hydrocarbon energy supplies such as nuclear, hydro, wind, solar, biomass, and bio-liquids, noting the opportunities and challenges associated with each energy source.

The Supply Task Group formed nine subgroups organized into three functional groups to conduct its analyses: Data Interpretation/Database, Endowment, and Energy Infrastructure and Delivery. The results of the Supply Task Group's work are summarized in Chapter Two of this report.

Technology Task Group

The Technology Task Group focused on the examination of technological advances that may influence future energy use or sources. The more than 120 subject-matter experts who participated in the Technology Task Group were identified and organized into 14 subgroups around technical themes. The Technology Task Group then examined specific technical subjects as they related to these broad topics: transportation efficiency, nuclear, unconventional gas, heavy oil, coal-to-liquids/coal-to-gas, technology development and deployment, carbon management, shale oil/hydrates, exploration, deepwater, conventional/EOR/arctic, and human resources. In particular, the team was requested to address time horizons for potential technology deployment, research budgets, and the science and engineering capabilities required to support development.

The results of the discussion, debate, and insights provided by the Technology Task Group are in Chapter Three of this report and integrated with the analyses found in the Supply and Demand chapters.

Geopolitics & Policy Task Group

The Geopolitics & Policy Task Group operated as two distinct teams as the study progressed. During the study analysis phase, the Geopolitics Team assessed how sovereign national, regional, and global policy decisions might affect global supply and demand outlooks. The Geopolitics Team included regional scholars as well as industry, academic and NGO participants. Topics addressed included broad issues such as governance, security, globalism, and climate and the environment. The Geopolitics chapter reflects the integrated content of those working documents and the discussion, debate and insights provided by the group at large.

The Policy team was formed toward the conclusion of the study and included representatives of other study teams involved in the effort as well as a contingent of outside experts drawn from the policy community. The group was used primarily to analyze and vet the various study findings and policy recommendations advanced by the Task Groups. Final selection of the most significant recommendations was performed by the CSC and working groups made up of its members.

Cross-Cutting Groups

Each Task Group began by posing a set of framing questions to guide its work. These framing questions highlighted a need for a number of cross-cutting groups to focus on topics of concurrent interest to several Task Groups. The cross-cutting groups were staffed by subject matter experts typically from two or more Task Groups. Subjects investigated included macroeconomics, gas-to-liquids/coal-to-liquids, biofuels/renewables, infrastructure, parallel studies, carbon management, refining, transportation, nuclear power, and coal.

Integration Team

The Task Groups shared information through the cross-cutting groups and by arranging overlapping membership. Even with these ongoing linkages, a broader effort was necessary to prepare integrated views of the global energy picture. An Integration Team was formed to summarize observations and findings, and to extract key conclusions. This team included members from the CSC and Task Groups, and identified the following overarching themes for review with the Policy Team and the full CSC.

- Economic growth, energy demand, and demand moderation
- Fossil energy supply and delivery
- Non-fossil energy supply and delivery
- Energy security and interdependence
- Carbon management
- Infrastructure
- Industry capacity
- Technology.

Through a process of reviews, the findings and observations were refined into the "hard truths" of this study, and formed the basis of proposed strategies and recommendations.

INFORMATION MANAGEMENT

An Analytical Approach

While the study scope was evolving, the Task Groups began assembling data for their analyses. As illustrated in Figure 7-5, the data streams used by the Task Groups for their analysis drew on public and proprietary information. In addition, a number of recent parallel studies from the energy sector were reviewed for relevant information and data.

Storing Information—The Data Warehouse

To make the study's broad-ranging and original sources easily available to all participants, a data warehouse was developed. This provided for centralized management of the multidimensional data collected. By the time it concluded, the study had compiled and used nearly 100 energy forecasts or outlooks. These forecasts and several hundreds of papers/documents on various aspects of the energy sector were used in the interpretations that formed the basis of the study findings and recommendations.

As an organizing feature, a digital survey questionnaire was developed to collect a consistent set of

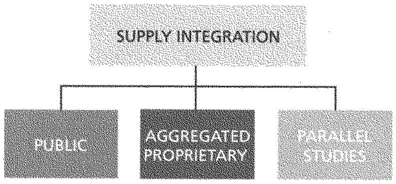


FIGURE 7-5. *Multiple Data Sources*

historical and forecast data for all data streams. The survey captured both numeric data and the assumptions used in individual energy outlooks.

The data request was very comprehensive although not all of the respondents completed all aspects of the survey. Data were requested at the world, regional and also key country levels. The regions surveyed were organized in these broad headings: North America, Central and South America, OECD, Non-OECD Europe and Asia/Oceania, the Middle East, and Africa.

The data warehouse was designed to be the main analytical tool for the Task Groups, accepting all data collected from the survey questionnaire and other data sources. As the survey data were multi-dimensional, Oracle OLAP database technology was used and the collection was organized using 7 dimensions:

1. Time *(year)*
2. Geography *(country or geographic region)*
3. Energy type *(e.g., oil, gas, coal, nuclear, renewable)*
4. Energy sector *(e.g., commercial, residential)*
5. Case type *(e.g., business as usual, alternative energy policy)*
6. Units *(applicable unit of measure)*
7. Source *(e.g., public, proprietary)*

Once in the data warehouse, selected values or ranges of values for any or all dimensions could be applied as a filter to enable analysis.

The questionnaire collected high-level assumptions, oil and natural gas endowment, oil production, natural gas production, coal energy supply, the methodology used by the different outlooks, economic/demographic information, energy prices, total energy consumption, energy production and electricity generation, and environmental information. Additional supply data were developed for liquefied natural gas and gas-to-liquids, infrastructure, and biomass/biofuels.

The review process produced supply data sets associated with the key documents that were identified and collected. These data sets cover a wide range of views, including low-end projections, mid-range and reference cases, and high-end forecasts. Each data set generated represents a unique and consistent forecast. Several organizations provided multiple scenarios, each of which was documented as a separate case for evaluation.

The contents of the Data Warehouse and a viewer application are available on the CD that accompanies this report (see Appendix E).

Public Data and Information

Each of the Task Groups searched the literature for integrated, global energy supply/demand forecasts that extended until at least 2030 and were in the public domain. Five forecasts were found that met these criteria, three from the U.S. Energy Information Administration and two from the International Energy Agency (Table 7-1).

To capture an even more comprehensive set of forecasts, the study identified a "wide net" of additional public sources. About 80 additional organizations and individuals were enlisted to participate by contributing data in a standard survey format. Among the sources for the wide-net data were: DOE, National Coal Council, OPEC, Greenpeace, Pew, SAIC, Natural Resources Defense Council, Climate Change Science Program, European Commission, and the Association for the Study of Peak Oil.

Energy Information Administration
International Energy Outlook [illegible]

- Reference Case
- High Case (economic growth, oil price)
- Low Case (economic growth, oil price)

International Energy Agency
World Energy Outlook [illegible]

- Reference Case
- Alternative Policy Case

TABLE 7-1. Integrated, Global Energy Supply/Demand Forecasts

In addition to the data gathered from other public domain sources, Energy Secretary Bodman sent letters in October 2006 to 19 governments, advising them of the study and seeking their participation, comments, and contributions. The countries were Australia, Azerbaijan, Brazil, Canada, Peoples Republic of China, Germany, India, Indonesia, Japan, Kazakhstan, Kuwait, Mexico, Nigeria, Norway, Qatar, Russia, Saudi Arabia, United Arab Emirates, and United Kingdom.

Proprietary Data and Information

To supplement and test the major public domain projections, an analysis of aggregated proprietary information was also undertaken. The "National Petroleum Council Survey of Global Energy Supply/Demand Outlooks" was sent to 34 international oil companies and consulting groups that were believed to make this type of projection. No study participant had access to individual, proprietary survey responses or knew which organizations were among the respondents. A list of organizations to which the survey was sent is shown in Table 7-2.

In addition to quantitative data, the questionnaire also requested high-level assumptions, oil and natural gas endowment, oil production, natural gas production, coal energy supply, the methodology used by the different outlooks, economic/demographic information, energy prices, total energy consumption, energy production and electricity generation, and environmental information. Additional supply data were developed for liquefied natural gas and gas-to-liquids, infrastructure, and biomass/biofuels.

Because of the commercial value of these data, and to ensure strict compliance with all antitrust requirements, the data were collected and aggregated by an independent accounting firm, Argy, Wilze and Robinson (AWR), which was charged with maintaining the anonymity and confidentiality of the responses. No one outside this independent third-party organization had access to individual, proprietary survey responses or even knew which organizations were among the respondents.

As the aggregator of the proprietary data, AWR was tasked with:

- Receiving the survey responses from responding organizations.

International Oil Companies
BP
Chevron
ConocoPhillips
Eni S.p.A.
Exxon Mobil Corporation
Marathon Oil Company
PetroCanada
Reliance Industries Limited
Repsol
Shell
Total S.A.
Valero
Consultants and Others
Barclays Capital
Bernstein Research Group
Cambridge Energy Research Associates
Caterpillar Inc.
Chemical Data Inc.
CRA International, Inc.
Deutsche Bank
Global Insight, Inc.
Goldman, Sachs & Co.
Jacobs Consultancy Inc.
Lawrence Berkeley National Laboratory
McKinsey Global Institute
Oak Ridge National Laboratory
PFC Energy
PIRA Energy Group
Probe Economics, Inc
Purvin & Gertz, Inc.
Rocky Mountain Institute
Simmons and Company International
SRI International
Wood Mackenzie Ltd.
Ziff Energy Group

TABLE 7-2. *Recipients of the NPC Survey of Global Energy Supply/Demand Outlooks*

- Clarifying with the survey respondent any responses that appeared inconsistent or incorrectly entered. The NPC required that the aggregator also engage an independent technical expert, who operated under the same confidentiality requirements as any other employee of the aggregator, to assist in reviewing the survey responses.
- Provided that at least three responses were received from a group of respondents (i.e., International Oil Companies or Consultants), preparing a report for that group of the aggregated survey data and the individual qualitative responses after suitable editing to preclude identifying any specific response with a specific respondent.
- Submitting a draft report of the aggregated and de-identified responses to the NPC's outside antitrust counsel as an additional check to ensure compliance with the reporting guidelines.
- Following up as necessary and issuing an amended final report if the NPC requested that specific items in the report be clarified.

The data were aggregated separately for the International Oil Companies and the Consulting Companies, and again for combined groupings.

For each of the groups separately, provided at least three responses were received for each group, AWR reported:

- The highest values for each quantitative response (where at least three values were reported) and associated qualitative responses.
- The lowest values for each quantitative response (where at least three values were reported) and associated qualitative responses.
- The average values for each quantitative response (where at least three values were reported) and associated qualitative responses.

Then, for all the responses combined, AWR reported:

- For the two responses with the highest total global energy use in 2030, a report of the average of all quantitative responses where two responses were reported, and all qualitative responses.
- For the two responses with the lowest total global energy use in 2030, a report of the average of all quantitative responses where two responses were reported, and all qualitative responses.
- For all responses, a report of the average of all quantitative responses where at least two responses were reported, and all qualitative responses.

Following completion of its report, AWR was required to destroy all survey responses, working papers, notes, and any other record of the survey responses, keeping only the survey report.

As a result of the proprietary data collection, 29 cases from 21 respondents were incorporated into the 9 aggregations that now reside in the data warehouse—International Oil Companies (low, average, and high energy use); Consulting Companies (low, average, and high energy use), and the combined low, average, and high responses from all the International Oil Company and Consultant respondents. The response rate for the International Oil Companies was 75 percent or greater, with the response rate from the Consulting Companies less than 75 percent.

Parallel Studies

A parallel studies process examined numerous other recent public reports that addressed various aspects of energy policy to inform the work of the NPC study's Coordinating Subcommittee. (Appendix D provides summaries of these parallel studies.) The reports included are shown in Table 7-3.

SUMMARY

The NPC study, *Facing the Hard Truths about Energy*, differs from most of the parallel studies we reviewed by its depth of analysis, its breadth of sources and participants, and its balanced perspectives. The methodology adopted by the study team included a comprehensive review of multiple supply and demand outlooks to 2030. This effort was further extended by the Task Groups and cross-cutting groups to include assessments of technology, infrastructure, alternative energy sources, security, and the environment. This methodology enabled the team to create and recommend a core set of five strategies for the nation to pursue. Solutions to the energy challenges will depend on the cooperation of government and industry, in the United States and around the world, to create the necessary opportunities for a balanced future—including economic, security, and environmental goals.

- National Commission on Energy Policy
- Energy Security Leadership Council
- Business Roundtable Energy Task Force
- National Association of Manufacturers
- Council on Foreign Relations
- Alliance for Energy and Economic Growth
- World Energy Council/US Energy Association
- IEA World Energy Outlook 2006
- U.S. DOE/EIA International Energy Annual 2006
- ExxonMobil Outlook for Energy
- NETL Oil Peaking Study
- U.S. Government Accountability Office
- American Enterprise Institute
- Intergovernmental Panel on Climate Change
- Stern Review Report
- Global Roundtable on Climate Change
- World Energy Technology Outlook – 2050
- 2000-2050 North American Transportation Energy Futures
- UN Foundation (Scientific Expert Group)
- CNA – National Security and the Threat of Climate Change
- MIT – The Future of Coal in a Carbon-Constrained World
- EPRINC – Ethanol and U.S. Energy Security
- U.S. Climate Action Partnership
- Council of the Americas – Energy Action Group
- OPEC Secretariat – World Oil Outlook 2007
- Energy Charter – Oil & Gas Pricing Study

TABLE 7-3. *Studies Examined*

APPENDICES

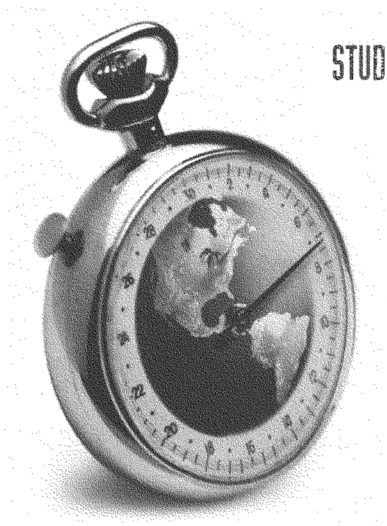
APPENDIX A
REQUEST LETTER & DESCRIPTION OF THE NPC

APPENDIX B
STUDY GROUP ROSTERS

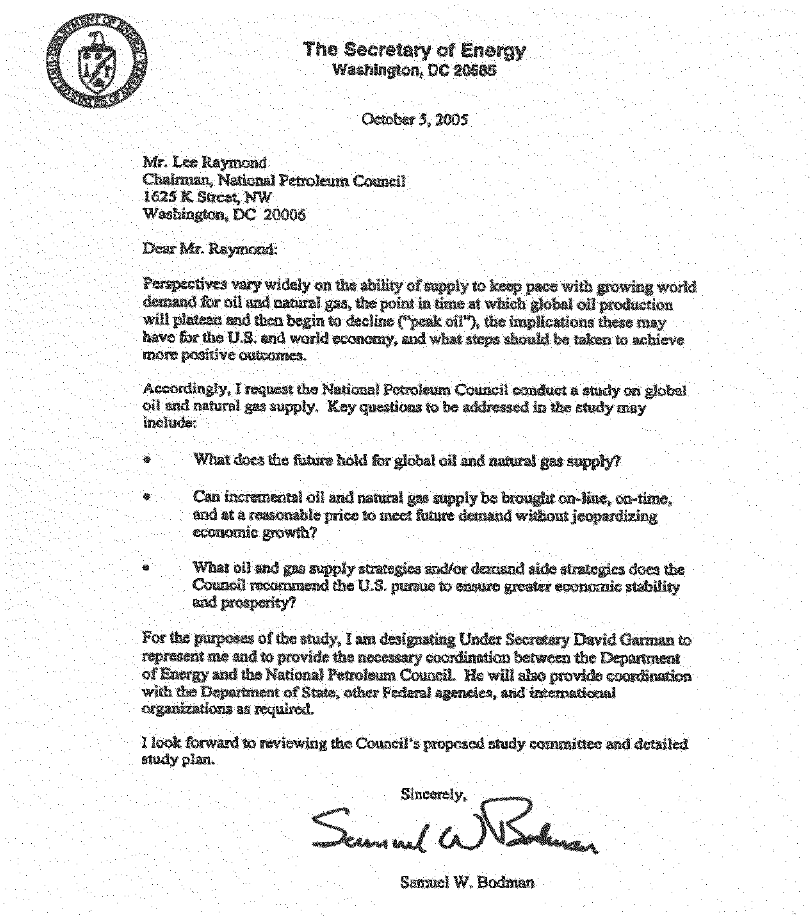
APPENDIX C
STUDY OUTREACH PROCESS AND SESSIONS

APPENDIX D
PARALLEL STUDIES

APPENDIX E
ADDITIONAL MATERIALS ON THE CD



APPENDIX A
REQUEST LETTER & DESCRIPTION OF THE NPC



The Secretary of Energy
Washington, DC 20585

October 5, 2005

Mr. Lee Raymond
Chairman, National Petroleum Council
1625 K Street, NW
Washington, DC 20006

Dear Mr. Raymond:

Perspectives vary widely on the ability of supply to keep pace with growing world demand for oil and natural gas, the point in time at which global oil production will plateau and then begin to decline ("peak oil"), the implications these may have for the U.S. and world economy, and what steps should be taken to achieve more positive outcomes.

Accordingly, I request the National Petroleum Council conduct a study on global oil and natural gas supply. Key questions to be addressed in the study may include:

- What does the future hold for global oil and natural gas supply?
- Can incremental oil and natural gas supply be brought on-line, on-time, and at a reasonable price to meet future demand without jeopardizing economic growth?
- What oil and gas supply strategies and/or demand side strategies does the Council recommend the U.S. pursue to ensure greater economic stability and prosperity?

For the purposes of the study, I am designating Under Secretary David Garman to represent me and to provide the necessary coordination between the Department of Energy and the National Petroleum Council. He will also provide coordination with the Department of State, other Federal agencies, and international organizations as required.

I look forward to reviewing the Council's proposed study committee and detailed study plan.

Sincerely,

Samuel W Bodman

Samuel W. Bodman

DESCRIPTION OF THE NATIONAL PETROLEUM COUNCIL

In May 1946, the President stated in a letter to the Secretary of the Interior that he had been impressed by the contribution made through government/industry cooperation to the success of the World War II petroleum program. He felt that it would be beneficial if this close relationship were to be continued and suggested that the Secretary of the Interior establish an industry organization to advise the Secretary on oil and natural gas matters.

Pursuant to this request, Interior Secretary J. A. Krug established the National Petroleum Council (NPC) on June 18, 1946. In October 1977, the Department of Energy was established and the Council was transferred to the new department.

The purpose of the NPC is solely to advise, inform, and make recommendations to the Secretary of Energy on any matter requested by the Secretary, relating to oil and natural gas or the oil and gas industries. Matters that the Secretary would like to have considered by the Council are submitted in the form of a letter outlining the nature and scope of the study. The Council reserves the right to decide whether it will consider any matter referred to it.

Examples of studies undertaken by the NPC in the last 20 years include:

- *Factors Affecting U.S. Oil & Gas Outlook* (1987)
- *Petroleum Storage & Transportation* (1989)
- *Industry Assistance to Government – Methods for Providing Petroleum Industry Expertise During Emergencies* (1991)
- *Petroleum Refining in the 1990s – Meeting the Challenges of the Clean Air Act* (1991)
- *The Potential for Natural Gas in the United States* (1992)
- *U.S. Petroleum Refining – Meeting Requirements for Cleaner Fuels and Refineries* (1993)
- *The Oil Pollution Act of 1990: Issues and Solutions* (1994)
- *Marginal Wells* (1994)
- *Research, Development, and Demonstration Needs of the Oil and Gas Industry* (1995)
- *Future Issues – A View of U.S. Oil & Natural Gas to 2020* (1995)
- *U.S. Petroleum Product Supply—Inventory Dynamics* (1998)
- *Meeting the Challenges of the Nation's Growing Natural Gas Demand* (1999)
- *U.S. Petroleum Refining—Assuring the Adequacy and Affordability of Cleaner Fuels* (2000)
- *Securing Oil and Natural Gas Infrastructures in the New Economy* (2001)
- *Balancing Natural Gas Policy—Fueling the Demands of a Growing Economy* (2003)
- *Observations on Petroleum Product Supply* (2004).

The NPC does not concern itself with trade practices, nor does it engage in any of the usual trade association activities. The Council is subject to the provisions of the Federal Advisory Committee Act of 1972.

Members of the National Petroleum Council are appointed by the Secretary of Energy and represent all segments of the oil and natural gas industries and related interests. The NPC is headed by a Chair and a Vice Chair, who are elected by the Council. The Secretary of Energy serves as the NPC's Government Cochair. The Council is supported entirely by voluntary contributions from its memhers.

Additional information on the Council's origins, operations, and reports can be found at www.npc.org.

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2006-2007

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NATIONAL PETROLEUM COUNCIL

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Study group and outreach participants contributed in a variety of ways, ranging from full-time work in multiple study areas, to involvement on a specific topic, to reviewing proposed materials, or to participating solely in an outreach session. Involvement in these activities should not be construed as endorsement or agreement with all the statements, findings, and recommendations in this report. Additionally, while U.S. government participants provided significant assistance in the identification and compilation of data and other information, they did not take positions on the study's policy recommendations.

As a federally appointed and chartered advisory committee, the National Petroleum Council is solely responsible for the final advice provided to the Secretary of Energy. However, the Council believes that the broad and diverse study group and outreach participation has informed and enhanced its study and advice. The Council is very appreciative of the commitment and contributions from all who participated in the process.

This appendix lists the individuals who served on this study's Committee, Coordinating Subcommittee, Task Groups, and Subgroups as a recognition of their contributions. In addition, the National Petroleum Council wishes to acknowledge the numerous other individuals and organizations who participated in some aspects of the work effort through workshops, outreach meetings, and other contacts. Their time, energy, and commitment significantly enhanced the study and their contributions are greatly appreciated.

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APPENDIX C
STUDY OUTREACH PROCESS AND SESSIONS

This appendix provides descriptions of the outreach process and sessions conducted for this study.

In addition to conducting a systematic review and evaluation of available information on the future oil and gas supply and demand picture, the study desired to ensure an open process that would be fully transparent to individuals, organizations, and non-U.S. governments with interests in global energy issues. Most importantly, the National Petroleum Council (NPC) wished to ensure that the study's approach would address the broad range of global issues associated with energy.

To solicit input from such a broad perspective of individuals and organizations, the NPC conducted an extensive communications outreach effort during the early phases of the study. Members from the various study groups and NPC staff participated in over 30 study outreach sessions with organizations and individuals with interests in the global energy issues. These sessions involved more than 1,000 individuals. Slide presentations were used to outline the reason for the study—Secretary Bodman's request, the planned scope of work, the study's organization and staffing, and how the study would proceed to conclusion. Participants were encouraged to offer comments during the sessions and to submit further comments if they so wished.

Sessions were held with representatives of members of the U.S. Congress and Congressional committees, non-governmental organizations (NGOs) of diverse interests, other third-parties, business associations, a wide-range of energy-related professional and trade associations, and, very importantly, non-U.S. government energy ministries. The comments received as a result of these sessions were captured and forwarded to the appropriate study group(s) for review and use during the fact-finding and analysis process.

Background information about the study—its scope, format, and progress, including updated versions of status presentations—was posted on the NPC's publicly accessible website, www.npc.org.

Outreach sessions were conducted with the following individuals and organizations:

- U.S. Congressional Staffs:
  - Staff Members, U.S. Senate Energy Committee
  - Staff Representative, U.S. Senate Foreign Relations Committee
  - Staff Representative, U.S. House of Representatives Committee on International Relations, Subcommittee on Middle East and Central Asia
  - Staff Member, U.S. Senator Feinstein
  - Staff Members, U.S. Senate Finance Committee
  - Staff Members, Joint Committee on Taxation
- Environmental NGOs:
  - Friends of the Earth
  - Alliance to Save Energy
  - National Environmental Trust
  - World Resources Institute
  - Resources for the Future
  - American Council for an Energy-Efficient Economy
  - Natural Resources Defense Council
- Non-environmental NGOs:
  - National Democratic Institute
  - International Crisis Group
  - Human Rights Watch
  - International Republican Institute

  - Mercy Corps
  - International Rescue Committee
  - Catholic Relief Services
  - USAID
- Other Pertinent Organizations:
  - International Energy Agency
  - National Commission for Energy Policy
  - Saudi National Security Assessment Project
  - Organization of Petroleum Exporting Countries (OPEC)
  - American Enterprise Institute
- General Business Associations:
  - U.S. Chamber of Commerce
  - Business Roundtable
  - National Association of Manufacturers
- Energy-Related Professional and Trade Associations:
  - American Petroleum Institute
  - National Petrochemical and Refiners Association
  - Center for Liquefied Natural Gas
  - Methane Hydrate Advisory Committee
  - American Association of Petroleum Geologists
  - Hedburg Conference on World Oil Resources
  - Independent Petroleum Association of America
  - American Gas Association
  - American Chemistry Council
  - Natural Gas Supply Association
  - Society of Petroleum Engineers
  - National Coal Council

Also, letters and/or phone calls were placed by representatives of the Department of Energy to the following U.S. government executive departments, inviting their participation, comments, and input:

- U.S. Department of the Interior
- U.S. Department of Agriculture
- U.S. Department of State
- U.S. Department of Transportations
- U.S. Department of Defense
- U.S. Environmental Protection Agency
- U.S. Department of the Treasury
- U.S. Department of Commerce
- U.S. Trade Representative
- Federal Energy Regulatory Commission
- Interstate Oil & Gas Compact Commission

In addition to the data-gathering methodology described elsewhere, Secretary Bodman sent letters in October 2006 to the following non-U.S. governments advising them of the study and seeking their participation, comments, and input:

- Australia
- Azerbaijan
- Brazil
- Canada
- Peoples Republic of China
- Germany
- India
- Indonesia
- Japan
- Kazakhstan
- Kuwait
- Mexico
- Nigeria
- Norway
- Qatar
- Russia
- Saudi Arabia
- United Arab Emirates
- United Kingdom

NPC study representatives were assigned responsibility for conducting follow-up contacts to provide more background information on the study and to elicit input from non-U.S. governments. Input received was forwarded to the appropriate study group(s) for review and use in the study. Visits were made to a number of energy ministries and representatives of non-U.S. governments and companies participated in some meetings of the study's Coordinating Subcommittee. Also, study status reports were sent in April and July 2007 to update all those initially contacted by Secretary Bodman.

APPENDIX D
PARALLEL STUDIES

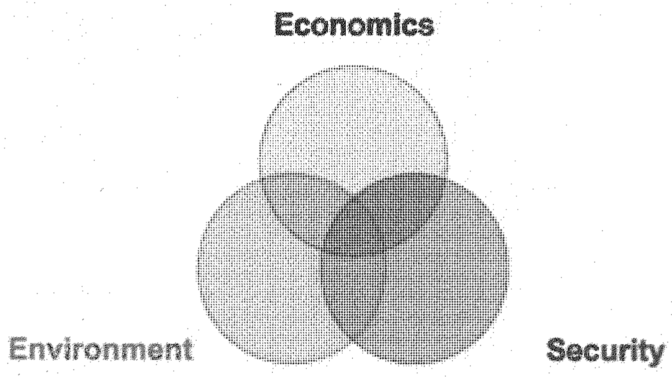
PROCESS AND SUMMARIES

The summaries in this appendix were prepared by the NPC based on studies authored or published by other organizations, and are used with permission. To obtain a complete version of any study, readers should contact the study's sponsoring organization. Contact information is included in each summary. Nothing in this appendix should be understood as indicating endorsement or sponsorship by any other organization or the NPC.

Parallel Studies

A Parallel Studies process, which examined numerous recent reports regarding aspects of energy policy, was employed to inform the work of the NPC study's Coordinating Subcommittee. This process found that:

- Most current energy studies tend to be dominated by one or at most two of the three key concerns that we believe are critical to a complete understanding of global oil and natural gas.
- The best energy strategies for the U.S. to pursue to ensure greater economic stability and prosperity are likely to be found at the intersection of these three circles.



Reports Examined

Reports (Listed in Order Examined) **Page**

National Commission on Energy Policy D-6
Energy Security Leadership Council D-11
Business Roundtable Energy Task Force D-15
National Association of Manufacturers –
  Resources and Environmental Policy D-16
Council on Foreign Relations – Energy Task Force D-17
Alliance for Energy and Economic Growth – Energy Summit D-18
World Energy Council / US Energy Association – National Energy Policy D-19
IEA World Energy Outlook 2006 .... D-20
US DOE/EIA International Energy Annual 2007 .... D-22
ExxonMobil Outlook for Energy D-26
NETL Oil Peaking Study D-30
US Government Accountability Office – Peak Oil D-31
American Enterprise Institute – Climate and Tax Policies D-34
Intergovernmental Panel on Climate Change D-36
Wikipedia – Global Cooling/Warming D-41
NewScientist Magazine – The Solar Effect D-42
Stern Review Report – Economics of Climate Change D-43
The Earth Institute – Global Roundtable on Climate Change D-45
EC World Energy Technology Outlook – 2050 .... D-47
DOE – 2000-2050 North American Transportation Energy Futures D-48
UN Foundation – Confronting Climate Change D-49
CNA – National Security and the Threat of Climate Change D-50
MIT – The Future of Coal in a Carbon-Constrained World D-51
EPRINC – Ethanol and US Energy Security D-53
US Climate Action Partnership – A Call for Action D-55
Council of the Americas – Energy Action Group D-56
OPEC Secretariat – World Oil Outlook 2007 .... D-57
Energy Charter Secretariat – Oil & Gas Pricing Study D-59

Overall Findings of Policy Studies

General Agreement on Policy Objectives

- Encourage Market Solutions
- Increase Energy Efficiency
- Ensure Access to Supplies
- Encourage Fuel Diversity
- Reduce Price and Supply Volatility
- Strengthen Energy Infrastructure
- Develop New Energy Technologies
- Protect the Environment

Overall Findings of Policy Studies

Diversity of Policies and Concerns

- CAFE standards
- Carbon taxes, caps, regulations
- Subsidies for alternate fuels
- Limits to imports / or to demand growth
- Efficiency standards
- Peak oil
- Data transparency
- Market imperfections / Over-regulation

NATIONAL COMMISSION ON ENERGY POLICY

National Commission on Energy Policy

- A consensus set of recommendations that aims to enhance American national security, strengthen the US economy, and protect the global environment and public health.

Leadership: John Holdren (Harvard University & Woods Hole Research Center)
William Reilly (Aqua Int'l Partners, formerly US EPA)
John Rowe (Exelon Corporation)

Structure: A bipartisan group of 20 energy experts – representing the senior ranks of industry, government, academia, labor, consumer and environmental protection organizations, with more than a dozen experienced analytical staff.

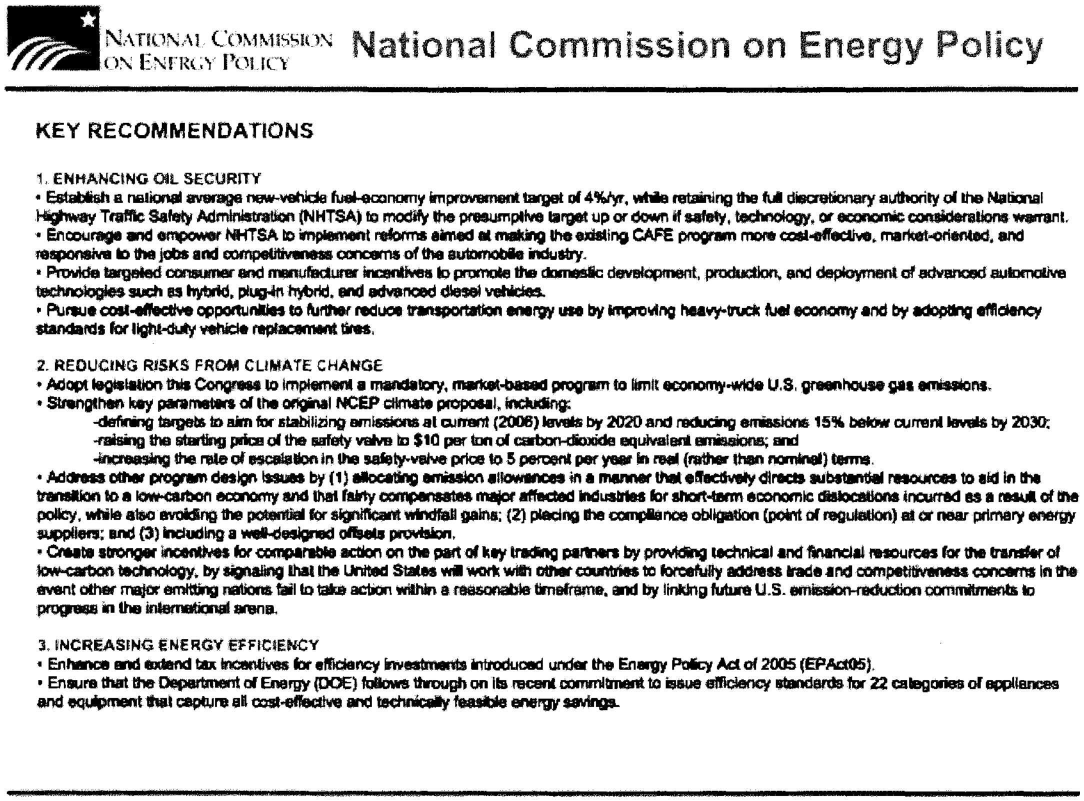
Timelines: Main study published in December 2004: Ending the Energy Stalemate:
Key recommendations at http://www.energycommission.org/files/finalReport/O82F4692.pdf

Updated recommendations published April 2007

Other reports/workshops include:
- US Energy Infrastructure Vulnerability (June 2006)
- Design Issues in Market-based Greenhouse Gas Reduction Strategies (Feb 2006)
- Oil Shockwave – An Oil Crisis Executive Simulation (June 2005)

- Recommendations considered a thoughtful set of policies. Has made modest progress in a highly partisan Congressional atmosphere. Latest proposals include (1) increased auto efficiency standards, (2) interim nuclear waste storage, (3) deployment of carbon capture and storage technologies, and (5) a national renewable energy standard.

Website: **http://www.energycommission.org/**



National Commission on Energy Policy

KEY RECOMMENDATIONS

1. ENHANCING OIL SECURITY

- Establish a national average new-vehicle fuel-economy improvement target of 4%/yr, while retaining the full discretionary authority of the National Highway Traffic Safety Administration (NHTSA) to modify the presumptive target up or down if safety, technology, or economic considerations warrant.
- Encourage and empower NHTSA to implement reforms aimed at making the existing CAFE program more cost-effective, market-oriented, and responsive to the jobs and competitiveness concerns of the automobile industry.
- Provide targeted consumer and manufacturer incentives to promote the domestic development, production, and deployment of advanced automotive technologies such as hybrid, plug-in hybrid, and advanced diesel vehicles.
- Pursue cost-effective opportunities to further reduce transportation energy use by improving heavy-truck fuel economy and by adopting efficiency standards for light-duty vehicle replacement tires.

2. REDUCING RISKS FROM CLIMATE CHANGE

- Adopt legislation this Congress to implement a mandatory, market-based program to limit economy-wide U.S. greenhouse gas emissions.
- Strengthen key parameters of the original NCEP climate proposal, including:
    -defining targets to aim for stabilizing emissions at current (2006) levels by 2020 and reducing emissions 15% below current levels by 2030;
    -raising the starting price of the safety valve to $10 per ton of carbon-dioxide equivalent emissions; and
    -increasing the rate of escalation in the safety-valve price to 5 percent per year in real (rather than nominal) terms.
- Address other program design issues by (1) allocating emission allowances in a manner that effectively directs substantial resources to aid in the transition to a low-carbon economy and that fairly compensates major affected industries for short-term economic dislocations incurred as a result of the policy, while also avoiding the potential for significant windfall gains; (2) placing the compliance obligation (point of regulation) at or near primary energy suppliers; and (3) including a well-designed offsets provision.
- Create stronger incentives for comparable action on the part of key trading partners by providing technical and financial resources for the transfer of low-carbon technology, by signaling that the United States will work with other countries to forcefully address trade and competitiveness concerns in the event other major emitting nations fail to take action within a reasonable timeframe, and by linking future U.S. emission-reduction commitments to progress in the international arena.

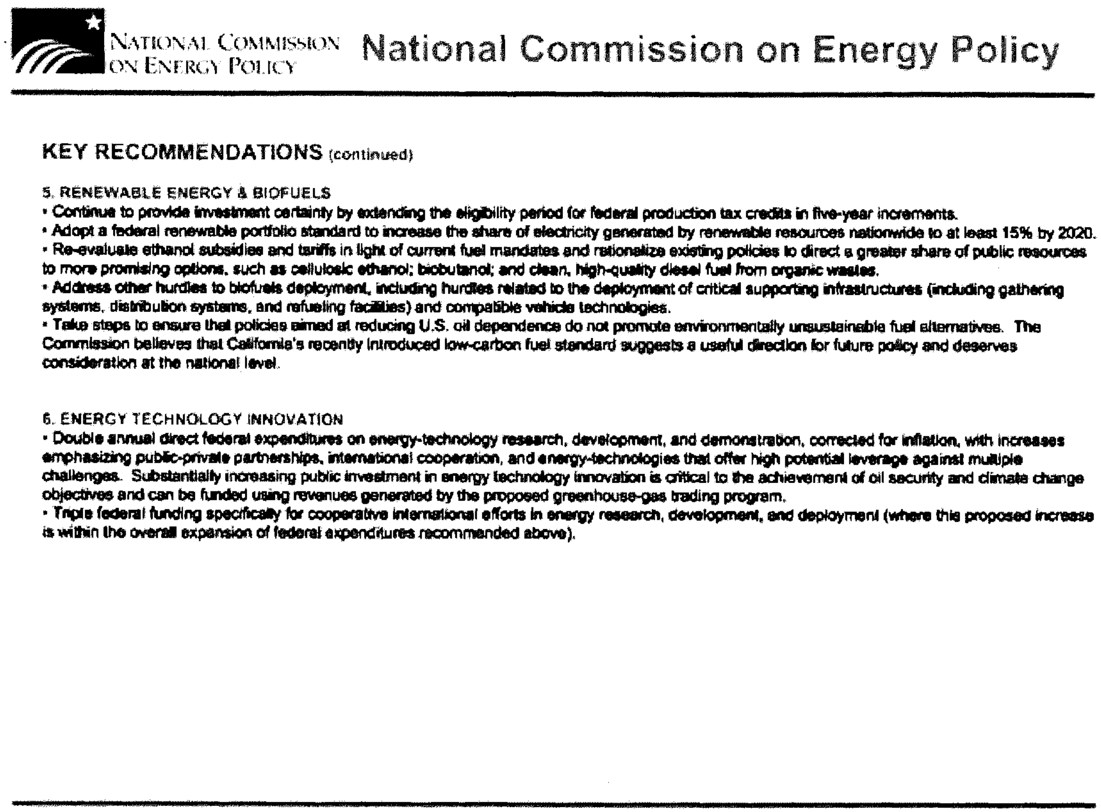
3. INCREASING ENERGY EFFICIENCY

- Enhance and extend tax incentives for efficiency investments introduced under the Energy Policy Act of 2005 (EPAct05).
- Ensure that the Department of Energy (DOE) follows through on its recent commitment to issue efficiency standards for 22 categories of appliances and equipment that capture all cost-effective and technically feasible energy savings.

KEY RECOMMENDATIONS (continued)

4. NATURAL GAS/ COAL / NUCLEAR

- Continue to focus on assuring future supply adequacy by following through on EPAct05 commitments with respect to the Alaska pipeline, LNG infrastructure, market transparency, and permitting and leasing. The Commission reiterates its call for a comprehensive inventory of on- and off-shore resources to inform future policy decisions and urges Congress to address concerns about the adequacy of related provisions in EPAct05 (both in terms of the relatively short timeframe specified for completing the inventory and in terms of constraints on the use of federal resources to conduct inventory-related activities in certain areas).
- Direct greater resources toward accelerating the commercialization of carbon capture and storage (CCS) by providing substantial deployment incentives. Specifically, the Commission believes CCS projects should be eligible for bonus allowances under a greenhouse gas trading program that are at least equal in value to incentives provided under the renewable energy production tax credit.
- Condition eligibility for public funding or subsidies on the actual inclusion of CCS with any new IGCC and other advanced coal projects going forward. CCS must be included from the outset in any taxpayer supported efforts to develop coal-to-liquids technology.
- Explore carbon capture options for non-IGCC plants.
- Ensure that the U.S. Environmental Protection Agency (EPA) completes a rigorous, formal public process to formulate effective regulatory protocols governing long-term carbon storage as soon as possible (recognizing that midcourse corrections will likely be needed as experience is gained).
- Ensure that new coal plants built without CCS are not "grandfathered" (i.e., awarded free allowances) in any future regulatory program to limit greenhouse gas emissions.
- Take action to address the current impasse on nuclear waste disposal, while reaffirming the ultimate objective of siting and developing one or more secure geologic disposal facilities, by amending the Nuclear Waste Policy Act (NWPA) to:
    - Align its requirements with human engineering and scientific capabilities, while adequately protecting public health and safety and the environment.
    - Require DOE to site and operate consolidated national or regional interim storage options.
    - Undertake R&D to explore technological alternatives to the direct geologic disposal of waste from a once-through cycle that meet commercial requirements and non-proliferation objectives, reduce the challenge of waste disposal, ensure adequate protection of public health and safety, and extend fuel supply.
    - Codify that interim storage and federal responsibility for disposal of nuclear waste is sufficient to satisfy the Nuclear Regulatory Commission's waste confidence requirement.
    - Require the Secretary of Energy to take possession of and/or remove fuel from reactor sites that have been, or are in the process of being fully decommissioned.



NATIONAL COMMISSION ON ENERGY POLICY

National Commission on Energy Policy

KEY RECOMMENDATIONS (continued)

5. RENEWABLE ENERGY & BIOFUELS

- Continue to provide investment certainty by extending the eligibility period for federal production tax credits in five-year increments.
- Adopt a federal renewable portfolio standard to increase the share of electricity generated by renewable resources nationwide to at least 15% by 2020.
- Re-evaluate ethanol subsidies and tariffs in light of current fuel mandates and rationalize existing policies to direct a greater share of public resources to more promising options, such as cellulosic ethanol; biobutanol; and clean, high-quality diesel fuel from organic wastes.
- Address other hurdles to biofuels deployment, including hurdles related to the deployment of critical supporting infrastructures (including gathering systems, distribution systems, and refueling facilities) and compatible vehicle technologies.
- Take steps to ensure that policies aimed at reducing U.S. oil dependence do not promote environmentally unsustainable fuel alternatives. The Commission believes that California's recently introduced low-carbon fuel standard suggests a useful direction for future policy and deserves consideration at the national level.

6. ENERGY TECHNOLOGY INNOVATION

- Double annual direct federal expenditures on energy-technology research, development, and demonstration, corrected for inflation, with increases emphasizing public-private partnerships, international cooperation, and energy-technologies that offer high potential leverage against multiple challenges. Substantially increasing public investment in energy technology innovation is critical to the achievement of oil security and climate change objectives and can be funded using revenues generated by the proposed greenhouse-gas trading program.
- Triple federal funding specifically for cooperative international efforts in energy research, development, and deployment (where this proposed increase is within the overall expansion of federal expenditures recommended above).

NATIONAL COMMISSION ON ENERGY POLICY

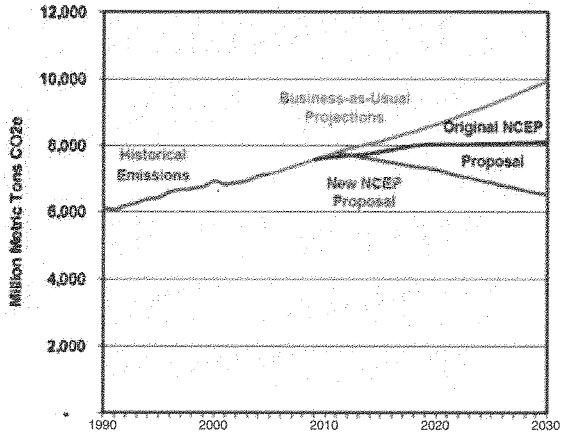
National Commission on Energy Policy

GHG PROPOSAL REVISED

While strengthening the overall stringency of its Greenhouse Gas (GHG) mitigation proposal, the new Commission proposal continues to rely on the core program elements first articulated in its 2004 report, especially: emission targets within a cap and trade system; providing market-based incentives for deployment of low-carbon technologies; linkage to greenhouse gas mitigation action by major U.S. trading partners, including China and India; and a cost-containment mechanism to prevent undue harm to the U.S. economy.

The reductions in greenhouse gas (GHG) emissions would result from a series of new policies proposed by the Commission, beginning with a revision of key elements of its initial cap and trade proposal for mitigating U.S. emissions. The proposal announced today increases the proposed "safety valve" or "cost cap" of the NCEP program from $7 to $10 per ton of carbon-dioxide equivalent emissions, and would increase the safety valve price by 5 percent above inflation per year. In addition, the Commission's new carbon cap does not rely on an "emissions intensity" metric, but instead calls for specific numerical reductions in greenhouse gas emissions for a given year.

Greenhouse Gas Emission Targets



The Commission's original proposal envisioned an initial ten-year implementation period during which program targets would first aim to slow the rate of growth in US emissions before proceeding to "stop" and "reverse" phases in which emissions would stabilize and then begin to decline. The Commission's new proposal strengthens the program targets to begin emissions reductions immediately upon implementation and achieve a 15% reduction below current emissions levels by 2030.

Business-as-usual projections for greenhouse gas emissions are taken from the Energy Information Administration's Annual Energy Outlook 2006.

ENERGY SECURITY
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Energy Security Leadership Council

Securing America's
Future Energy

The Council, a project of Securing America's Future Energy (SAFE), is led by Co-Chairmen Frederick W. Smith, Chairman and CEO of FedEx Corporation, and General P.X. Kelley (Ret.), former Marine Corps Commandant and member of the Joint Chiefs of Staff. The Energy Security Leadership Council includes prominent business and military leaders who support a comprehensive, long-term policy to reduce US oil dependence and improve energy security. The Council will work aggressively to build bipartisan support. SAFE is committed to reducing America's dependence on oil in order to improve our national security and strengthen the economy, while increasing US exports, protecting the environment, and creating US jobs.

Other members include Admiral Dennis Blair, USN (Ret.), CIC, US PACOM; Admiral Vern Clark, USN (Ret), former Chief of Naval Operations; Michael L. Eskew, Chairman and CEO, UPS, Inc; Adam Goldstein, President, Royal Caribbean International; General John A. Gordon, USAF (Ret.), former Homeland Security Advisor to the President; Maurice Greenberg, Chairman and CEO, C.V. Starr & Co., Inc.; Admiral Gregory Johnson, USN (Ret.), Commander, US Naval Forces, Europe; Robert Hormats, Vice Chairman, Goldman Sachs International; Herbert Kelleher, Exec.Chairman, Southwest Airlines; John F. Lehman, former Secretary of the US Navy; Andrew Liveris, CEO, The Dow Chemical Company; General Michael E. Ryan, USAF (Ret.), 16th Chief of Staff, USAF; David P. Steiner, CEO, Waste Management, Inc.; and General Charles F. Wald, USAF (Ret.), Former Deputy Commander, US European Command. Edgar M. Bronfman, Retired Chairman, The Seagram Company Ltd.; Jeffrey C. Sprecher, Chairman, IntercontinentalExchange (ICE); Josh S. Weston, Honorary Chairman, Automatic Data Processing, Inc.

SAFE has produced:

☐ **The Wescott Report:** This report gives an overview of the broad economic effects of a scenario in which oil prices surge to $120 a barrel due to coordinated terrorist attacks on global oil transportation infrastructure. The scenario was the basis for a simulation exercise conducted at the World Economic Forum Annual Meeting 2006 in Davos, Switzerland.

☐ **Oil ShockWave:** A scenario exercise developed by SAFE and the National Commission on Energy Policy (NCEP). This half-day simulation provided participants and observers with an opportunity to think through simulated emergency situations--in this case involving oil supply disruptions. (June 2005)

☐ Recommendations to the Nation on Reducing US Oil Dependence: December 2006

Website: **http://www.secureenergy.org/**

ENERGY SECURITY
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Energy Security Leadership Council

Securing America's
Future Energy

Recommendations to the Nation on Reducing US Oil Dependence: December 2006

I. REDUCE OIL CONSUMPTION

A. Significantly reform and then annually strengthen fuel efficiency standards for passenger cars and light-duty trucks.

— Reform the Corporate Average Fuel Economy (CAFE) system in order to make it more market-, size-, and attribute-based and to allow for the application of different but increasingly stringent standards.

— Set a target of 4% for annual increases in fuel efficiency of all passenger cars and light-duty trucks weighing up to 10,000 lbs.

— Allow "off-ramps" if 4% is technically infeasible, unsafe, or not cost-effective for a given year.

B. Fund significant financial incentives for the domestic production and purchase of highly fuel efficient vehicles.

— Lift the current 60,000 vehicle-per-manufacturer cap on tax incentives for the purchase of advanced technology efficient vehicles.

— Link the tax credit to the miles-per-gallon performance of the vehicles.

— Provide tax incentives for retooling to all manufacturers with existing U.S. facilities.

Projected savings: 4.3 million barrels of oil per day (mbd)

II. PROVIDE ALTERNATIVES

A. Grow the supply and demand sides of the biofuels market by creating incentives and obligations for infrastructure deployment, requiring increasing production of Flexible Fuel Vehicles (FFVs), and increasing federal assistance available for "first-mover" production of cellulosic ethanol and other promising large-volume biofuels.

— Create obligations and provide tax credits for installing ethanol fuel pumps and related infrastructure. Limit the credit for corporate-owned and branded stations when oil prices are high.

— Require 10% annual increases in the production of FFVs so that all major production models are compatible with rich ethanol blends by 2015.

— Establish a competitive program employing a variety of financial tools—grants, tax credits, direct loans, and loan guarantees—for federal assistance to six or more biorefineries employing a variety of feedstocks and located in various regions of the country.

Projected ethanol output: 30 billion gallons per year = 2.0 mbd

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Future Energy

Recommendations to the Nation on Reducing US Oil Dependence: December 2006 (continued)

III. EXPAND SUPPLY

A. Increase access to U.S. oil and natural gas reserves on the Outer Continental Shelf (OCS) with sharply increased and expanded environmental protections.

— Increase access to OCS oil and natural gas reserves with appropriate third-party monitoring, increased surety bond requirements, clear penalties for environmental damages to avoid protracted litigation, stronger administration of the current leasing program, and protection of coastal vistas.

Projected production: 1.0–2.0 mbd

B. Employ federal funds to accelerate the development and deployment of Enhanced Oil Recovery (EOR) techniques.

Projected production: 1.0 mbd

C. Make investment access a high profile aspect of U.S. trade negotiations and diplomatic efforts with oil-producing nations.

IV. MANAGE RISKS

A. In light of military threats to the global oil infrastructure, the U.S. should, where appropriate:

— Encourage burden sharing with U.S. allies and partners, including producing and consuming nations, in defense of global oil flows;

— Foster formal and informal security arrangements on multilateral, regional, and bilateral bases, capitalizing on the U.S.'s unique ability to arrange international security efforts;

— Provide diplomatic support as well as counter-terrorism training and military aid so that oil-producing nations can better assist in protecting petroleum supplies,

— Offer assistance to producing countries in their efforts to develop attractive investment climates backed by stable civil societies; and

B. Reassess the multiple dimensions of strategic reserves policy within the U.S. and at the International Energy Agency (IEA). In addition, revise the 1974 Organization for Economic Cooperation and Development (OECD) agreement to allow China and India to join the IEA and participate in updated global strategic petroleum reserve arrangements.

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Corollary Recommendations (December 2006)

I. REDUCE OIL CONSUMPTION

A. Extend federal subsidies for hybrid medium-duty vehicles (Classes 3–6) to 2012 and remove the cap on the number of eligible vehicles. Set and then annually increase fuel efficiency standards for medium-duty vehicles. Set the standards consistent with the energy efficiency benefits of hybridization. Projected savings: 0.2 mbd

B. Set and then annually strengthen fuel efficiency standards for heavy-duty vehicles (Class 7 and 8), employing federal subsidies as suitable. Projected savings: 0.9 mbd

C. Increase allowable weight to 97,000 lbs. gross vehicle weight for tractor-trailer trucks that have a supplementary sixth axle installed but which replicate current stopping distances and do not fundamentally alter current truck architecture. Further study the safety impacts of significantly longer and heavier tractor-trailers used in conjunction with slower speed limits. If safety can be proven, implementation could generate major efficiencies while simultaneously reducing road congestion and other non-fuel costs. Projected savings: will vary with extent of implementation

D. Require the Federal Aviation Administration (FAA) to implement improvements to commercial air traffic routing in order to increase safety and decrease fuel consumption. Projected savings: 0.4 mbd

II. PROVIDE ALTERNATIVES

A. Reform current ethanol per gallon subsidies to encourage private-sector investment in domestic ethanol and alternative biofuels production and infrastructure. "Smart subsidies" will secure the industry against short-term oil price drops, minimize the cost to the U.S. Treasury, and distinguish between feedstock technologies. Balance the benefits of domestic production capability with the advantages of environmentally responsible development of an International biofuels trade.

B. Grow the biodiesel market, while ensuring a biodiesel standard that mandates quality and reliability to satisfy the operational standards of users and also includes clear and consistent labeling of biodiesel blend ratios. Projected output: 3.3 billion gallons per year ≈ 0.2 mbd

C. Support federal investment in research, development, and commercialization of carbon sequestration technologies that can limit the adverse emissions impacts of oil shale, oil sands, and coal-to-liquids (CTL) production.

III. EXPAND SUPPLY and MANAGE RISKS

A. Increase access to U.S. reserves in Alaska. Increase access to Alaskan reserves with appropriate third-party monitoring, increased surety bond requirements, clear penalties for environmental damages to avoid protracted litigation, and stronger administration of the current leasing program. Projected production: 0.9 mbd

B. Evaluate policy approaches to expand the ability of U.S. refineries to process a wider variety of crude stocks and to make U.S. refining less vulnerable to extreme weather. Work to expand total U.S. capacity or to ensure that the U.S. will have secure access to product produced overseas.

Business Roundtable

Business Roundtable

- The Business Roundtable is an association of 160 chief executive officers of leading US companies that comprise nearly a third of the total value of the US stock market. The Energy Task Force was created in early 2006 to address the impact of higher energy costs on economic growth. CEOs report that rising energy costs are one of the top two cost pressures on their businesses and, as such, are committed to identifying solutions. Roundtable launched a comprehensive energy report publicly on June 6, 2007.
- Leadership, Michael G. Morris, CEO, American Electric Power Company,
  coordinated by Tony Kavanagh, AEP, and Marian Hopkins, Director - Public Policy, Business Roundtable

More Diverse, More Domestic, More Efficient: A Vision for America's Energy Future

Improving Energy Efficiency in the Commercial, Residential and Electric Power Sectors
The United States should reduce energy intensity by at least 25 percent above the anticipated business-as-usual rate by:

- Substantially boosting the efficiency of new and existing commercial and residential buildings
- Deploying a broad portfolio of energy efficient technologies for building operations and appliances
- Increasing the efficiency of the transmission and distribution system
- Optimizing the power grid with new or advanced technologies to save energy and improve reliability
- Encouraging smart metering and other strategies that reduce peak period demand on the grid
- Improving the efficiency of the nation's power plant fleet through upgrades at existing units and by constructing new advanced technology units
- Accelerating the deployment of wind and solar-thermal power generation
- Increasing reliance on efficient combined heat and power (CHP) units at industrial facilities
- Challenging individual companies to set and meet ambitious energy efficiency goals

Increasing Energy Security in the Transportation Sector
The United States should aggressively reduce transportation fuel demand and diversify supply by:

- Developing and deploying energy efficient vehicle technologies to the maximum extent feasible
- Enhancing conventional domestic oil production by raising refinery output and expanding access to currently off-limit petroleum reserves, including reserves in Alaska
- Scaling up to 10% ethanol in gasoline as quickly as possible, undertaking intensive R&D on advanced biofuels such as biobutanol and cellulosic ethanol, and expanding their presence in fuel supply as warranted by technology advances in the vehicles and fuels sectors
- Increasing production of transportation fuels from unconventional sources like shale oil and coal-to-liquids processes
- Moderating fuel demand by adopting policies that reduce vehicle congestion and idling, and growth in vehicle miles traveled per capita
- Maintaining access to the world's energy resources by preserving the integrity of free markets and opportunities for robust foreign investment by our energy industry

Achieving a Better Supply/Demand Balance in Natural Gas Markets
The United States should provide stable and affordable supplies of natural gas over the long-term by:

- Increasing domestic production through expanded access to natural gas supplies in the Rocky Mountains, the Atlantic and Pacific Coasts, Alaska and the Eastern Gulf of Mexico
- Augmenting conventional natural gas supplies through gasification of coal and bio-mass
- Expanding our liquefied natural gas import and pipeline infrastructure
- Moderating demand through energy efficiency in the power distribution and home heating sectors

Maintaining a Viable and Growing Nuclear Power Sector
The United States should maintain a viable and growing nuclear power sector by:

- Establishing an efficient, predictable licensing system for new nuclear power plants
- Providing effective financial incentives for new plants
- Implementing a workable and effective program for the management and disposal of spent nuclear fuel

Website: **http://www.businessroundtable.org/pdf/Energy/Business_Roundtable_Energy_Report_06062007.pdf**

National Association of Manufacturers

Resources and Environmental Policy Department

Congressional Checklist:

- Reduce Energy Intensity: Establish a national goal for decreasing the energy intensity of the U.S. economy by 30 percent by 2021.
- Strengthen and Make Permanent the R&D Tax Credit: The credit is now set to expire for the thirteenth time. To stay competitive, Congress must encourage U.S.-based R&D activities.
- Fund a New Office Within the Department of Education: The office would promote increased visibility of energy concepts within primary and secondary education curricula.
- Establish a New Office of Federal Lands Energy Project Streamlining: This office should be within the Executive Office of the President.
- Codify and Enhance Two Major Clean Air Act Regulations: The Clean Air Interstate Rule (CAIR) and the Clean Air Mercury Rule.
- Fully Fund All Federal Energy Research Authorized by EPAct 2005.
- Fund Nuclear Research: Congress should authorize $100 million for new university-based nuclear physics programs.
- Permanently Reauthorize the Price-Anderson Act: To assure compensation to the public in the event of a nuclear accident and appropriately limit private- sector liability.
- Authorize Interim Storage of Spent Fuel: Congress should allow temporary storage at existing DOE facilities and other sites approved by a state legislature and governor.
- Fund Fuel Research: Authorize $500 million annually for research and development in advanced fuel cycles and reprocessing/recycling of spent nuclear fuel.
- Authorize Reverse Auctions: Allow a system of reverse auctions for awarding federal assistance to solar, ethanol, organic municipal solid waste and silvicultural cellulose material plants.
- Address ANWR: Authorize the U.S. Department of Interior to begin leasing activities in ANWR.
- Address OCS: Lift moratoria and reverse withdrawals for oil and gas production in the Outer Continental Shelf.
- Update EPAct 2005: Extend EPAct 2005 refinery expensing for oil shales to 2020 and make coal liquefaction facilities eligible for the same treatment.
- Fund R&D Initiatives: Authorize $1 billion annually for R&D in oil shales, coal liquefaction and production of natural gas from methane hydrate formations, while providing incentives for the production of petroleum from oil shales and transportation fuels from coal liquefaction.
- Set Standards: Establish uniform standards for the production of biodiesel and ethanol.

Website: http://www.nam.org

Affordable and reliable energy is essential to the long-term health of the U.S. economy and its citizens. Lower energy prices mean greater take-home pay for American workers, and access to competitively priced energy enables domestic producers of chemicals, plastics, fertilizers, paper goods, glass, metals and food products to effectively compete in the global economy.

Impressively, energy efficiency in the United States has doubled since 1970. But, our country's need for energy has risen 47 percent due to a growing economy. While investing in new energy sources and continuing to boost efficiency gains will play critical roles in meeting our country's energy demands in the future, increasing access to domestic sources of reliable energy will be essential to the long-term health of U.S. industry as well as the American worker.

A robust, comprehensive and forward-looking energy policy must consist of five crucial elements:

- **Making a national commitment to further reducing the energy intensity of the U.S. economy and educating consumers;**
- **Strengthening and focusing on public-private research and development efforts;**
- **Making existing statutes and regulations rational;**
- **Increasing domestic power generation; and**
- **Increasing domestic energy supply.**

COUNCIL ON FOREIGN RELATIONS

A Nonpartisan Resource for Information and Analysis

CFR

The Council on Foreign Relations is an independent, national membership organization and a nonpartisan center for scholars dedicated to producing and disseminating ideas so that members, as well as policymakers, journalists, students, and interested citizens in the US and other countries, can better understand world and foreign policy choices.

Task Force Leadership: John Deutch and Jim Schlesinger, co-chairs; David Victor, Project Director

Other Participants: Graham Allison, Belfer Center; Norman Augustine, Lockheed Martin; Robert Belfer, Belfer Management; Steven Bosworth, The Fletcher School; Helima Croft, Lehman Brothers; Charles DiBona, Sentient Council; Jessica Einhorn, SAIS; Martin Feldstein; NBER; David Goldwyn, Goldwyn Int'l; Michael Granoff, Pomona Capital; Bennett Johnston; Johnston & Assoc; Arnold Kanter, The Scowcroft Group; Karin Lissakers, Soros Fund; Walter Massey, Morehouse College; Ernest Moniz, MIT; William Reilly, Aqua Int'l; Peter Schwartz, Global Business Network; Philip Sharp, RFF; James Steinberg, LBJ School; Linda Stuntz, Stuntz, Davis & Staffier; James Sweeney, Stanford Univ; Frank Verrastro, CSIS; J. Robinson West, PFC Energy

Recommends, "the adoption of incentives to slow and eventually reverse the growth in consumption of petroleum products, especially transportation fuels such as motor gasoline," and offers three options: a tax on gasoline; stricter and broader mandated Corporate Average Fuel Economy (CAFE) standards; and the use of tradable gasoline permits that would cap the total level of gasoline consumed in the economy.

Other recommendations include:

- Encourage supply of oil from all sources while recognizing that the world cannot "drill its way out of this problem."
- US should take a more active role in international arrangements to manage the revenues from oil in a more transparent way in oil-producing nations.
- Remove the protectionist tariff on imported ethanol. Increase efficiency of oil and gas use in the United States and elsewhere
- Switch from oil-derived products to alternatives. Biofuels have significant potential.
- The Task Force favors greater use of nuclear power today and notes that over time electricity can replace liquid fuels for transportation.
- Make the oil and gas infrastructure more efficient and secure. Reexamine the management of the US SPR.
- Increase investment in new energy technologies. Promote the proper functioning and efficiency of energy markets.
- US should help improve efficiency in NOCs. Revitalize international institutions such as the International Energy Agency (IEA).
- Establish an energy security directorate within the National Security staff.
- Engage the Secretary of Energy in any foreign policy deliberations that involve energy issues
- Include energy security considerations in all planning studies at the National Security Council, Defense and State departments, and the intelligence community.

Website: **http://www.cfr.org/energy**

Alliance for ENERGY & ECONOMIC GROWTH
Energy to secure America's future.

Alliance for Energy & Economic Growth

The Alliance for Energy and Economic Growth was formed in 2001 to build support for the adoption and implementation of a comprehensive, market-based energy policy that uses all forms of energy to meet consumer demand for reliable energy at reasonable prices, while at the same time ensuring the quality of the environment. The Alliance is a broad-based coalition of more than 1,200 members who develop, deliver, or consume energy from all sources.

The US Chamber of Commerce and the Nuclear Energy Institute (as founding sponsors) hosted an Energy Summit in July, 2006, "An Open National Discussion on US Energy Policy" Featuring: Samuel Bodman, Secretary of Energy, Dirk Kempthorne, Secretary of the Interior, Joseph T. Kelliher, FERC Chairman.

http://www.uschamber.com/issues/index/energy/060719_energyagenda.htm

Key policy recommendations include:
☐ Increase energy efficiency and conservation
☐ Ensure adequate energy supplies and generation
☐ Renew and expand the energy infrastructure
☐ Encourage investment in new energy technologies
☐ Provide energy assistance to low-income households
☐ Ensure appropriate consideration of the impact of regulatory policies on energy

The Alliance adopted a supplemental set of principles to help guide the debate on climate change:
☐ Promote the accelerated development, demonstration, and cost-effective commercial deployment of climate friendly technologies to reduce, avoid, or sequester greenhouse gas emissions
☐ Address barriers to the development, financing, regulation, storage, and use of domestic climate-friendly fuel sources
☐ Promote energy conservation and efficiency
☐ Preserve American jobs and the competitiveness of U.S. industry
☐ Minimize economic disruptions and disproportionate impacts on specific sectors or regions of the economy
☐ Permit maximum flexibility in achieving energy and environmental goals
☐ Recognize the economy-wide and international dimensions of the challenge
☐ Facilitate technology transfer to emerging economies to reduce the fastest growing emission sources globally and to include the participation of developing nations such as China and India

Website: **http://www.yourenergyfuture.org/**

World Energy Council

USEA
United States Energy Association

World Energy Council
US Energy Association

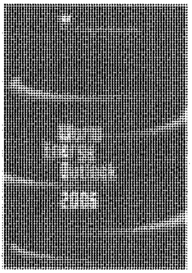
- **The World Energy Council** (WEC) covers all types of energy, including coal, oil, natural gas, nuclear, hydro, and renewables, and is UN-accredited, non-governmental, non-commercial and non-aligned. WEC is headquartered in London with member committees in 90 countries. Its goals include promoting research into the means of supplying and using energy having, short and long term, the greatest social benefit and the least harmful impact on the natural environment, and publishing or otherwise disseminating the results; holding of Congresses, workshops and seminars, to facilitate such supply and use of energy; and collaborating with other organizations in the energy sector.
  Website: http://www.worldenergy.org/wec-geis/default.asp

- **The United States Energy Association** (USEA) is the US member committee of the WEC. USEA is an association of public and private energy-related organizations. USEA sponsors policy reports and conferences dealing with global and domestic energy issues, as well as trade and educational exchange visits with other countries. The USEA published "Toward a National Energy Strategy" in February 2001 (and 10 other assessments of US Energy Policy. The policy recommendations were based on the results of workshops on key energy issues and a working group representing all sectors of the industry under the leadership of Richard Lawson, Chairman of its National Energy Policy Committee. Project was directed by Guy Caruso (now the head of the EIA at the US DOE).
  Website: http://www.usea.org

- **Recommendations include:**

  - Encourage energy supply expansion
  - Implement tax policies to spur capital investment
  - Encourage competitive markets regarding pricing and selection of fuels and energy suppliers
  - Increase funding for the low-income home energy assistance program and weatherization
  - Promote US leadership in energy development
  - Advocate market-based energy policies for foreign nations
  - Avoid unilateral trade and economic sanctions
  - Education programs to explain the importance of energy to economic security and development
  - Government programs should avoid favoring selective fuels or technologies
  - Improve the US energy transportation infrastructure
  - Comprehensive electric industry restructuring should promote efficient competition
  - Allow environmentally sound access to domestic resources
  - Government policies should promote energy efficiency
  - Eliminate tax rules the discourage foreign investment
  - Foster more open legal and institutional structures overseas
  - Focus R&D on a 20-30 year horizon
  - Regulatory predictability to stabilize investment decisions

International Energy Agency



World Energy Outlook 2006 published November 2006

Reference Scenario: No new government policies are adopted

Alternative Policy Scenario: Energy-security & climate-change policies now under consideration are adopted

Focus on Special Issues:
- Impact of higher energy prices
- Current oil and gas investment trends
- Outlook for nuclear power & biofuels
- Energy for cooking in developing countries (http://www.iea.org/textbase/weo/cooking.pdf)
- Brazil's energy outlook (http://www.worldenergyoutlook.org/Brazil.pdf)

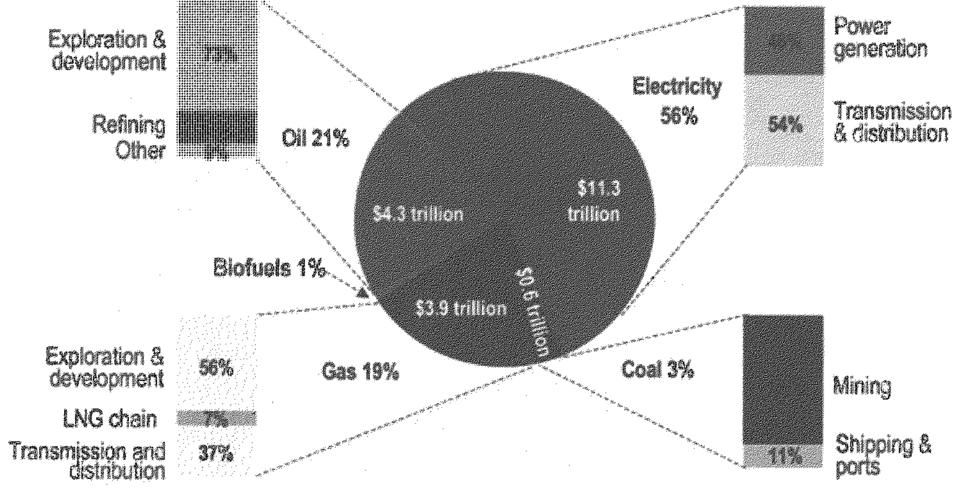
The world is facing twin energy threats:
  Inadequate and insecure supplies at affordable prices
  Environmental damage, including climate change

☐ Global energy system is on an unsustainable path
☐ Need to diversify energy sources & mitigate emissions is critical
☐ Urgent need to curb the growth in fossil-fuel demand & related emissions
☐ Strong new policies could sharply reduce the rate of increase in demand & emissions
☐ Economic cost of these policies would be more than outweighed by the economic benefits alone
☐ Governments need to tackle market barriers to ensure investment is forthcoming
☐ Considerable political will is needed to push policies through
☐ Rich countries need to help developing countries address energy poverty
☐ In the longer term, technology *development* will be critical to a sustainable energy system

Website: **http://www.worldenergyoutlook.org**

International Energy Agency

Cumulative Investment in Energy-Supply Infrastructure, 2005-2030 = $20.2 trillion (in $2005)



Source: IEA, World Energy Outlook 2006.

Energy Information Administration

Official Energy Statistics from the U.S. Government

International Energy Outlook 2007

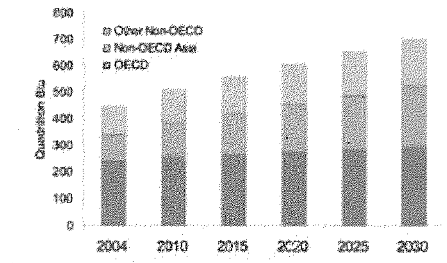
The Energy Information Administration (EIA) publishes its annual assessment of long-term world energy markets in its International Energy Outlook (IEO). The IEO2007 is the latest edition of this report and was released in May 2007; the NPC study, which was conducted prior to the IEO2007 release, is based upon the previous edition of this report, supplemented by projections from the Annual Energy Outlook 2007—the long-term outlook for U.S. energy markets. The report includes regional projections of world marketed energy use by fuel type (petroleum and other liquid fuels, natural gas, coal, nuclear power, and hydroelectricity and other renewable energy sources) and energy-related carbon dioxide emissions to the year 2030.

The projections in the IEO2007 provide an objective, policy-neutral reference case that can be used to analyze international energy markets. Models are abstractions of energy production and consumption activities, regulatory activities, and producer and consumer behavior. As a policy-neutral statistics and analysis organization, EIA does not propose, advocate, or speculate on future legislative and regulatory changes. Trends depicted in the analysis are indicative of tendencies in the real world rather than representations of specific real-world outcomes.

Highlights from the 2007 IEO include:

- In the IEO2007 reference case, world energy consumption is projected to increase by 57 percent between 2004 and 2030, rising to 702 quadrillion British thermal units (Btu).
- Much of the growth in worldwide energy use is projected for the non-OECD economies; energy use in the non-OECD exceeds that of the OECD by 2010.
- Non-OECD Asia (including China and India) accounts for half of the world's increase in marketed energy use in the IEO2007 reference case.
- World marketed energy consumption is projected to grow by 57 percent between 2004 and 2030, according to the reference case projection from the International Energy Outlook 2007 (IEO2007) released today by the Energy Information Administration (EIA). The IEO2007 shows the most rapid growth in energy demand for nations outside the Organization for Economic Cooperation and Development (OECD), especially in non-OECD Asia, where strong projected economic growth drives the increase in energy use.

World Marketed Energy Consumption by Region



Source: EIA, IEO2007

Website: http://www.eia.doe.gov/oiaf/ieo

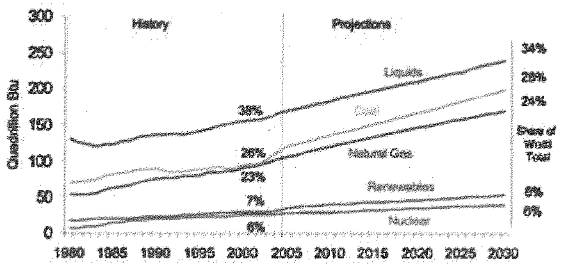
Energy Information Administration

Official Energy Statistics from the U.S. Government

International Energy Outlook 2007

- Petroleum and other liquid fuels remain the dominant energy source worldwide through 2030, though relatively high world oil prices in the mid-term erode their share of total energy use from 38 percent in 2004 to 34 percent in 2030.
- Coal is the fastest-growing energy source, increasing by 2.2 percent per year over the projection period.
- Higher fossil fuel prices, energy security concerns, improved reactor designs, and environmental considerations are expected to improve prospects for nuclear power capacity in many parts of the world, and a number of countries are expected to build new nuclear power plants. World nuclear capacity is projected to rise from 368 gigawatts in 2004 to 481 gigawatts in 2030. Declines in nuclear capacity are projected only in OECD Europe, where several countries (including Germany and Belgium) have either plans or mandates to phase out nuclear power, and where some old reactors are expected to be retired and not replaced.
- Higher fuel prices—especially for natural gas in the power sector, along with government policies and programs to support renewable energy, allow renewable fuels to compete economically. The renewable share of total world energy use increases from 7 percent in 2004 to 8 percent in 2030.

World Marketed Energy Use by Fuel Type



Source: EIA, IEO2007

World Energy Consumption by Fuel, 2004 -2030

(Quadrillion Btu)

	2004	2015	2030	Average Annual Percent Change 2004-2030
Liquids	168.2	197.8	238.9	1.4
Natural Gas	103.4	134.3	170.4	1.9
Coal	114.4	151.6	199.1	2.2
Nuclear	27.5	32.5	38.7	1.4
Renewables	33.2	43.4	53.5	1.9
Total	446.7	559.4	701.6	1.5

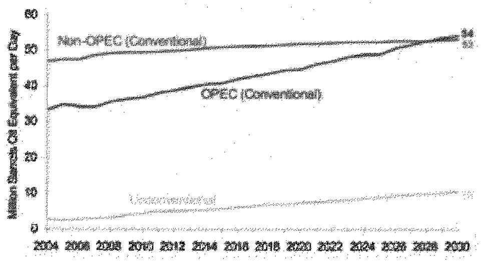
Energy Information Administration

Official Energy Statistics from the U.S. Government

International Energy Outlook 2007

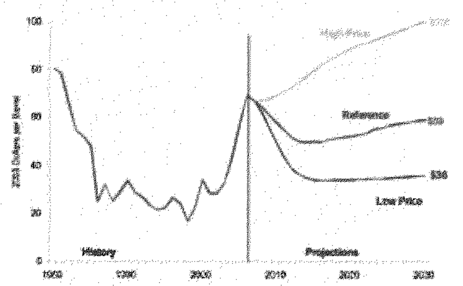
- In the IEO2007 reference case, world oil prices decline from $68 per barrel in 2006 (in real 2005 U.S. dollars) to $49 per barrel in 2014, then rise to $59 per barrel in 2030 ($95 per barrel on a nominal basis).
- High and low world oil price cases reflect the substantial degree of uncertainty about future oil prices. In 2030, prices range from $36 per barrel to $100 per barrel (real 2005 dollars) and the respective liquids demand ranges from 134 million barrels per day to 103 million barrels per day.

Worldwide Liquids Production



Source: EIA, IEO2007

World Oil Prices in Three Cases



Source: EIA, IEO2007

- To meet the increment in world liquids demand in the reference case, total supply in 2030 is projected to be 35 million barrels per day higher than the 2004 level of 83 million barrels per day.
- OPEC conventional production contributes about 21 million barrels per day to the total increase in supply; non-OPEC conventional another 8 million barrels per day to the increase.
- Unconventional resources (including biofuels, coal-to-liquids, and gas-to-liquids) are expected to become increasingly competitive and account for 9 percent of total world liquids supply in 2030, on an oil equivalent basis.

Energy Information Administration

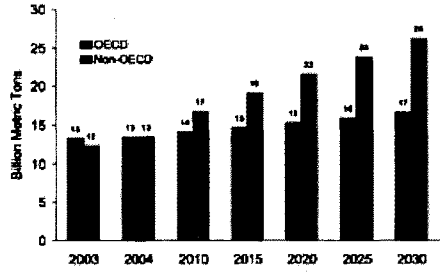
Official Energy Statistics from the U.S. Government

International Energy Outlook 2007

- The IEO2007 includes regional projections of delivered energy at the end use sector. In 2004 the OECD accounted for 44 percent of the world's industrial sector energy use; that share declines to 33 percent in 2030.

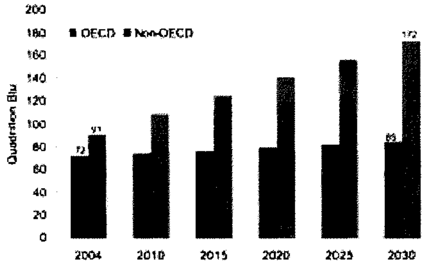
- Industrial sector energy use—driven by energy intensive industries—expands more rapidly in the non-OECD countries where investors are attracted by lower costs and fewer environmental constraints, than in the OECD countries.

Energy-Related World Carbon Dioxide Emissions



Source: EIA, IEO2007

Industrial Sector Energy Consumption



Source: EIA, IEO2007

- In the IEO2007 reference case, which does not include specific policies to limit greenhouse gas emissions, energy-related carbon dioxide emissions are projected to rise from 26.9 billion metric tons in 2004 to 33.9 billion metric tons in 2015 and 42.9 billion metric tons in 2030.

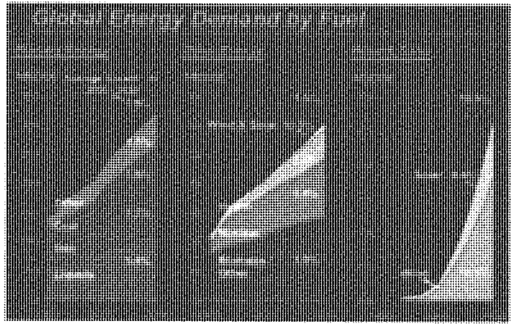
- From 2003 to 2004, carbon dioxide emissions from the non-OECD countries grew by almost 10 percent, while emissions in the OECD countries grew by less than 2 percent. The result of the large increase in non-OECD emissions was that 2004 marked the first time in history that emissions from the non-OECD exceeded those from the OECD countries.

- Because of the expectation that non-OECD countries will rely on fossil fuels to supply much of their future energy demand growth, carbon dioxide emissions from the non-OECD countries in 2030 are projected to exceed those from the OECD by 57 percent.

ExxonMobil

Taking on the world's toughest energy challenges.

The 2006 Outlook for Energy
A View to 2030



- Reflecting global population and GDP gains, we expect energy demand to rise by an average of 1.6% each year through 2030, reaching close to 325 million barrels per day of oil-equivalent (MBDOE). That's 60% higher than in 2000. Energy demand will rise fastest in non-OECD nations, which will account for approximately 80% of the global increase.
- A wide range of energy sources will contribute to meeting this growing global energy demand. Wind and solar energy, for example, are expected to grow at a rate of about 10 percent per year. But even at that rate, by 2030 they will likely still provide less than 1 percent of the world's total energy needs.
- Most of the world's growing energy needs through 2030 will continue to be met by oil, gas and coal. Today, fossil fuels account for 80% of energy usage, and that percentage is expected to remain stable through 2030.
- Driven by increasing needs in non-OECD countries, global liquids demand for transportation is expected to outpace gains in industrial and residential/commercial demand. Total liquids demand for transportation in 2030 will be about 65 million barrels a day, or about 50% higher than today.
- Ongoing access to affordable, reliable energy supplies is the foundation for future growth and prosperity around the globe.
- Meeting the world's growing energy needs will depend, as it has in the past, on advances in technology. Technology not only expands the range of where we produce, but it also extends the types of supplies available to meet demand. Many of the world's largest exploration and production projects are made possible by recent advances in technology.

Website: http://www.exxonmobil.com/Corporate/Citizenship/Imports/EnergyOutlook06/index.html

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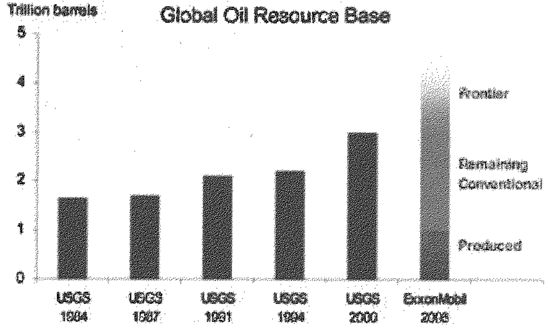
The 2006 Outlook for Energy
A View to 2030

- Technology (and prices) can impact estimates of oil resources. Global projections of the level of ultimately recoverable reserves for oil have grown over time.

- In 1984, the US Geological Survey (USGS) estimated that there were less than 2 trillion barrels of conventional oil that could be recovered globally. But that estimate has grown steadily, to more than 3 trillion barrels, as new technologies have expanded the possibilities for exploration and production.


Global Oil Resource Base

- The ExxonMobil "2006 Outlook for Energy" adds estimated "frontier" resources (such as heavy oil and shale oil) to "conventional" oil and estimates the world's recoverable oil base is over 4 trillion barrels. Since only about 1 trillion barrels of the world's conventional oil has been produced so far, we see ample resources available to meet growing demand for oil through 2030.

- Looking to 2030, we expect global liquids trade will increase more than 50%. Globally, more volume will originate from the Middle East and Russia/Caspian regions. Also significant will be increased flows to Europe and Asia Pacific.

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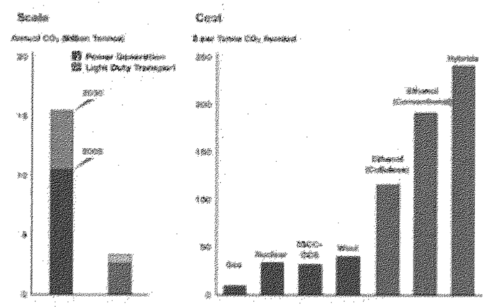
The 2006 Outlook for Energy
A View to 2030

- We expect global CO2 emissions to increase by 1.6%/yr through 2030, in line with overall energy growth and the expected uses of oil, gas and coal that result in CO2 emissions. Most of that growth will occur in the non-OECD countries, where strong energy demand growth along with heavy reliance on coal will drive CO2 emissions up by 2.6%/yr.

- Many options exist that will help mitigate CO2 emissions. Nuclear power is clearly an option, though it carries issues regarding new plant siting and waste management. Clean coal technology – where carbon is captured and sequestered – is another option, albeit a costly one. Other sectors are important too, including transportation, where we expect better vehicle technologies, including HCCI and hybrids, as well as cleaner fuels.

CO_2 Mitigation Options



- In terms of scale, power generation is the single largest source of CO2 emissions. CO2 emissions from this sector now total 10 billion tonnes per year, and by 2030 are likely to exceed 15 billion tonnes, or 40% of energy-related CO2 emissions. CO2 emissions from light-duty vehicle transportation are also significant, but far smaller.

- In the case of power generation, the lowest-cost mitigation option involves the use of natural gas to generate power compared to a conventional coal-fired power plant, while the highest-cost option shown above is wind power. In the middle-cost range are nuclear and clean-coal technologies with carbon capture and sequestration.

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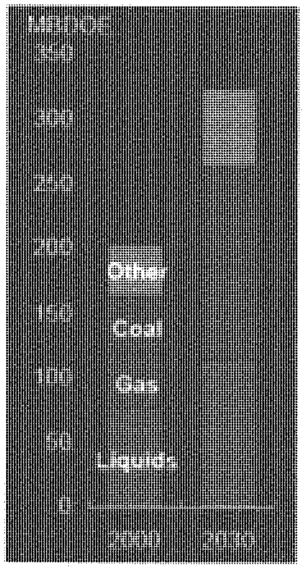
The 2006 Outlook for Energy
A View to 2030

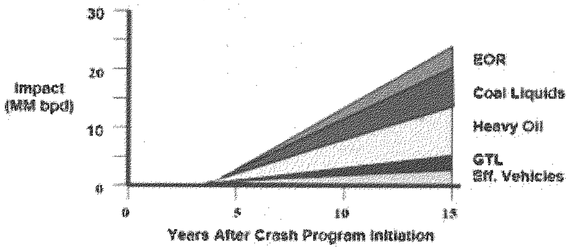


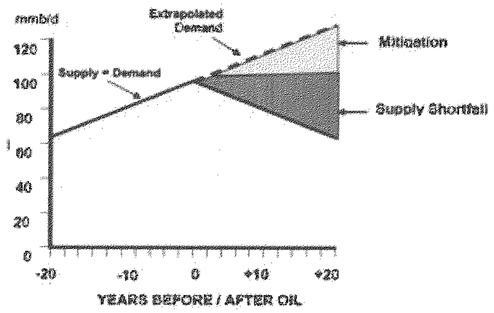
- By 2030, energy demand will increase by about 60% compared to 2000, driven by population growth and economic progress. While the vast majority of this increase will occur in non-OECD nations, efficiency gains throughout the world will remain important.
- The global energy mix will look very similar 25 years from now. Oil, gas and coal will be predominant.
- Resources are adequate to support global demand growth. However, access to these resources and large, timely investments will be needed to ensure people have access to reliable energy supplies. Global trade, particularly for oil and natural gas, will continue to grow.
- Providing this energy is not easy or automatic. Fortunately, many approaches exist which, working together, can help address these challenges. These include:
  - Supporting free and open markets to enable consumers to access the energy they need, and to spur continued innovation
  - Wise and efficient use of energy to help conserve global energy supplies and reduce greenhouse gas emissions
  - Technology advances to extend supplies and make the use of energy more efficient
  - Securing the benefits of energy trade in international markets to help ensure reliable and affordable supplies to meet growing demand

NETL THE ONLY U.S. NATIONAL LABORATORY
DEVOTED TO FOSSIL ENERGY TECHNOLOGY

PEAKING OF WORLD OIL PRODUCTION
IMPACTS, MITIGATION, & RISK MANAGEMENT

- ☐ The peaking of world oil production presents the US and the world with an unprecedented risk management problem. As peaking is approached, liquid fuel prices and price volatility will increase dramatically, and, without timely mitigation, the economic, social, and political costs will be unprecedented. Viable mitigation options exist on both the supply and demand sides, but to have substantial impact, they must be initiated more than a decade in advance of peaking.
- ☐ A unique aspect of the world oil peaking problem is that its timing is uncertain, because of inadequate and potentially biased reserves data from elsewhere around the world. In addition, the onset of peaking may be obscured by the volatile nature of oil prices.
- ☐ Oil peaking will create a severe liquid fuels problem for the transportation sector, not an energy crisis in the usual sense that term has been used.
- ☐ Waiting until world oil production peaks before initiating crash program mitigation leaves the world with a significant liquid fuel deficit for more than two decades.
- ☐ Initiating a mitigation crash program 20 years before peaking offers the possibility of avoiding a world liquid fuels shortfall for the forecast period.
- ☐ If mitigation were to be too little, too late, world supply/demand balance will be achieved through massive demand destruction (shortages), which would translate to significant economic hardship. With adequate, timely mitigation, the costs of peaking can be minimized.





Website:
http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf

GAO
Accountability • Integrity • Reliability

US Government Accountability Office

The Government Accountability Office, the audit, evaluation and investigative arm of Congress, exists to support Congress in meeting its constitutional responsibilities and to help improve the performance and accountability of the federal government. The GAO has published reports on a number of key energy issues and is currently working many on others. Among GAO's views, the agency recommends investigation of topics such as:

Ensure the Adequacy of National Energy Supplies and Related Infrastructure: Meeting rising demand could require significant investments into infrastructure such as power plants, transmission lines, refineries, and other key equipment and technologies.

Key Topics Needing Congressional Oversight

- Evaluate the risks, benefits, and implications for national security of investments that deepen US ties to international energy markets (e.g. overseas refineries, oil imports).
- Examine the Nuclear Regulatory Commission's licensing process for new power plants.
- Examine the implications of the Department of Energy's R&D portfolio.
- Assess development of evolving renewable energy markets.
- Evaluate programs that encourage energy efficiency and reduced energy demand.

Selected GAO Products

- Peak Oil GAO-07-283, February 2007
- Impact of petroleum inventories and refining capacity on refined product prices and price volatility (expected 2007)
- Strategic Petroleum Reserve. GAO-06-872, August 2006
- Issues Related to Potential Reductions in Venezuelan Oil Production. GAO-06-668, June 2006
- Natural Gas: Factors Affecting Prices and Potential Impacts on Consumers. GAO-06-420T. February 2006.
- Electricity Restructuring: Key Challenges Remain. GAO-06-237. November 2005.
- Meeting Energy Demand in the 21st Century: Many Challenges and Key Questions. GAO-05-414T. March 2005.

Website: **http://www.gao.gov**

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Peak Oil Study

Uncertainty about Future Oil Supply Makes It Important to Develop a Strategy for Addressing a Peak and Decline in Oil Production

What GAO Found

Most studies estimate that oil production will peak sometime between now and 2040. This range of estimates is wide because the timing of the peak depends on multiple, uncertain factors that will help determine how quickly the oil remaining in the ground is used, including the amount of oil still in the ground; how much of that oil can ultimately be produced given technological, cost, and environmental challenges as well as potentially unfavorable political and investment conditions in some countries where oil is located; and future global demand for oil. Demand for oil will, in turn, be influenced by global economic growth and may be affected by government policies on the environment and climate change and consumer choices about conservation.

In the US, alternative fuels and transportation technologies face challenges that could impede their ability to mitigate the consequences of a peak and decline in oil production, unless sufficient time and effort are brought to bear. For example, although corn ethanol production is technically feasible, it is more expensive to produce than gasoline and will require costly investments in infrastructure, such as pipelines and storage tanks, before it can become widely available as a primary fuel. Key alternative technologies currently supply the equivalent of only about 1% of US consumption of petroleum products, and the Department of Energy (DOE) projects that even by 2015, they could displace only the equivalent of 4% projected US annual consumption. In such circumstances, an imminent peak and sharp decline in oil production could cause a worldwide recession. If the peak is delayed, however, these technologies have a greater potential to mitigate the consequences. DOE projects that the technologies could displace up to 34% of US consumption in the 2025 through 2030 time frame. The level of effort dedicated to overcoming challenges will depend in part on sustained high oil prices to encourage sufficient investment in and demand for alternatives.

Federal agency efforts that could reduce uncertainty about the timing of peak oil production or mitigate its consequences are spread across multiple agencies and are generally not focused explicitly on peak oil. Federally sponsored studies have expressed concern over the potential for a peak, and agency officials have identified actions that could be taken to address this issue. For example, DOE and United States Geological Survey officials said uncertainty about the peak's timing could be reduced through better information about worldwide demand and supply, and agency officials said they could step up efforts to promote alternative fuels and transportation technologies. However, there is no coordinated federal strategy for reducing uncertainty about the peak's timing or mitigating its consequences.

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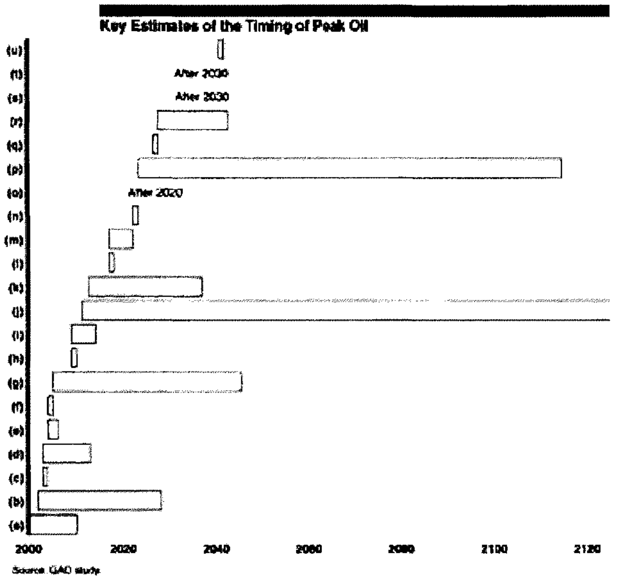
Peak Oil Study

Key Estimates of the Timing of Peak Oil



Source: GAO study.

Note: These studies are listed in appendix II of the GAO report. Estimates of 90 percent confidence intervals using two different reserves data sources are provided for study g. One additional study that is not represented in this figure, referenced as study v, states that the timing of the peak is "unknowable."

Why GAO Did This Study: The US economy depends heavily on oil, particularly in the transportation sector. World oil production has been running at near capacity to meet demand, pushing prices upward. Concerns about meeting increasing demand with finite resources have renewed interest in an old question: How long can the oil supply expand before reaching a maximum level of production—a peak—from which it can only decline?

How GAO Performed the Analysis: (1) examined when oil production could peak, (2) assessed the potential for transportation technologies to mitigate the consequences of a peak in oil production, and (3) examined federal agency efforts that could reduce uncertainty about the timing of a peak or mitigate the consequences. To address these objectives, GAO reviewed studies, convened an expert panel, and consulted agency officials.

What GAO Recommends: To better prepare for a peak in oil production, GAO recommends that the Secretary of Energy work with other agencies to establish a strategy to coordinate and prioritize federal agency efforts to reduce uncertainty about the likely timing of a peak and to advise Congress on how best to mitigate consequences.

American Enterprise Institute
for Public Policy Research

AMERICAN ENTERPRISE INSTITUTE

The American Enterprise Institute for Public Policy Research is a private, nonpartisan, not-for-profit institution dedicated to research and education on issues of government, politics, economics, and social welfare. AEI sponsors research and conferences and publishes books, monographs, and periodicals. Its website, www.aei.org, posts its publications, videos and transcripts of its conferences, biographies of its scholars and fellows, and schedules of upcoming events. A number of these postings relate to energy policy:

Strategic Options for Bush Administration Climate Policy (November 2006) book

Leo Lane, the executive director of the Climate Policy Center, explores options that policymakers might consider, as well as the costs and benefits of current policies. His conclusions will surprise many environmental advocates: President Bush was right to reject the Kyoto Protocol and should continue to reject calls for "cap-and-trade" programs modeled on Kyoto. Emissions trading would be expensive and ineffective; the costs would be significant but the environmental benefits would be negligible. With the threat of Kyoto-style cap-and-trade programs looming larger with each passing year, Lane argues that the Bush administration should consider adopting a modest carbon tax. This would be vastly more efficient than emissions trading and would cut off the growing political momentum towards reengaging with the Kyoto system. (At the very least, a cap should include a "safety valve," providing an unlimited supply of affordable credits, essentially transforming the trading program into a tax.) Lane also argues that greater attention should be paid to ambitious approaches to climate change such as geo-engineering and the development of breakthrough clean-energy technologies that could reduce emissions enough to curtail projected warming. Costly cap-and-trade programs that produce trivial reductions in greenhouse gas emissions are simply a waste of money; our resources should focus instead on actual solutions, not ineffective interim steps.

What Would a Rational Energy Tax Policy Look Like (November 2006) article

Kevin Hassett and Gilbert Metcalf explore tax policy options for energy, arguing that US energy tax policy is misguided in at least three ways. First, a policy to promote energy independence through reduced oil imports is based on a fundamental misunderstanding of how energy markets function. A policy that attempts to establish energy independence by promoting domestic fossil fuel production is especially misguided. Second, our policy relies heavily on energy subsidies, most of which are socially wasteful, inefficient, and driven by political rather than energy considerations. Third, current energy taxes are deficient on a number of levels. If one accepts the view that U.S. reliance on oil is a problem, then we can do much better than the policies mentioned above. A rational U.S. energy tax policy would include (1) an end to energy supply subsidies; (2) a green tax swap; (3) an end to the gas guzzler tax loophole and possible use of "feebates"; and (4) conservation incentive programs. Ending subsidies for fossil fuel production would level the playing field among energy sources and shift us from a policy of promoting fossil fuel supply to encouraging a reduction in fossil fuel consumption. It would also move us away from a woefully inefficient reliance on corn-based ethanol. A green tax swap uses revenue from environmentally motivated taxes to lower other taxes in a revenue-neutral reform. For example, Congress could reduce reliance on oil and other polluting sources of energy by implementing a carbon tax. The revenue could be used to finance corporate tax reform or reductions in the payroll tax.

Website: **http://www.aei.org**

American Enterprise Institute
for Public Policy Research

AMERICAN ENTERPRISE INSTITUTE

Climate Change: Caps vs. Taxes

Kenneth P. Green, Steven F. Hayward, Kevin A. Hassett. As the Kyoto Protocol's 2012 expiration date draws near, a general theme dominates the global conversation: leadership and participation by the United States are critical to the success of whatever climate policy regime succeeds the Kyoto Protocol. Two general policy approaches stand out in the current discussion. The first is national and international greenhouse gas (GHG) emissions trading, often referred to as "cap-and-trade." Cap-and-trade is the most popular idea at present, with several bills circulating in Congress to begin a cap-and-trade program of some kind. The second idea is a program of carbon-centered tax reform--for example, the imposition of an excise tax based on the carbon emissions of energy sources (such as coal, oil, and gasoline), offset by reductions in other taxes. In this paper we address the strengths and weaknesses of both ideas and the framework by which legislators should evaluate them.

http://www.aei.org/publications/filter.all,pubID.26286/pub_detail.asp

Website: **http://www.aei.org**

WMO INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE UNEP

The Intergovernmental Panel on Climate Change (IPCC) has been established by WMO and UNEP to assess scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts, and options for adaptation and mitigation. It is currently finalizing its Fourth Assessment Report "Climate Change 2007".

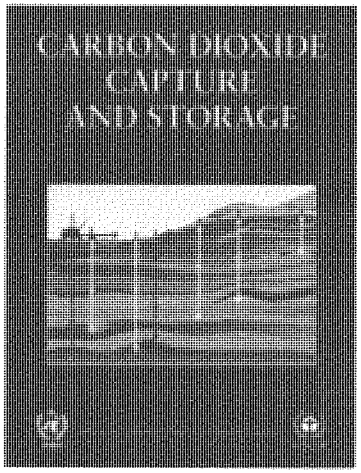
The Panel meets in plenary sessions about once a year. It accepts/approves/adopts IPCC reports, decides on the mandates and work plans of the Working Groups and the Task Force, the structure and outlines of its reports. A main activity of the IPCC is to provide in regular intervals an assessment of the state of knowledge on climate change. The reports by the three Working Groups provide a comprehensive and up-to-date assessment of the current state of knowledge on climate change.

The IPCC has three Working Groups:
- Working Group I assesses the scientific aspects of the climate system and climate change. Report published February 2007
- Working Group II assesses the vulnerability of socio-economic and natural systems to climate change, negative and positive consequences of climate change, and options for adapting to it. Report published April 2007
- Working Group III assesses options for limiting greenhouse gas emissions and otherwise mitigating climate change. Report published May 2007

The Synthesis Report for the Fourth Assessment Report will be released in November 2007.
This will provide the key findings of all three Working Groups of the IPCC Fourth Assessment Report.

Website: http://www.ipcc.ch

The graphic on this page depicts one of the many Special Reports undertaken by the IPCC.


CARBON DIOXIDE CAPTURE AND STORAGE

WMO

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

UNEP

CLIMATE CHANGE 2007

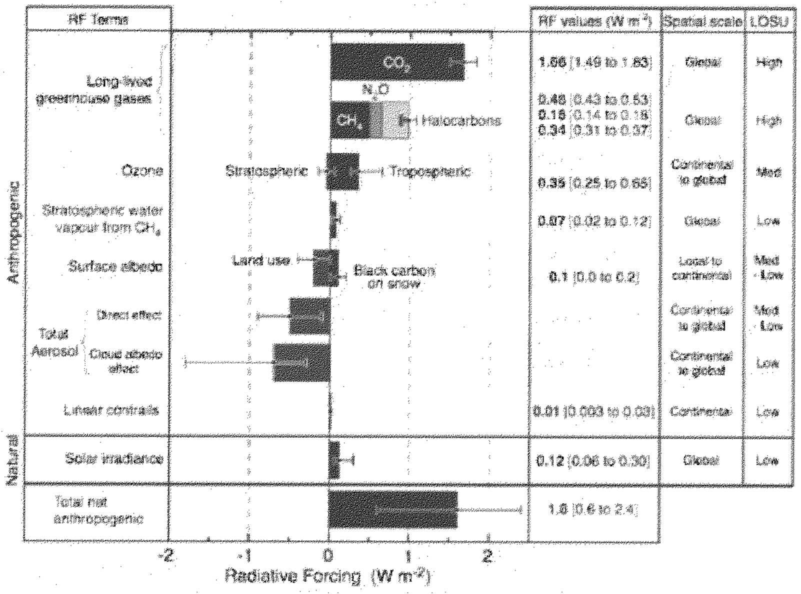
The Physical Science Basis

Working Group I

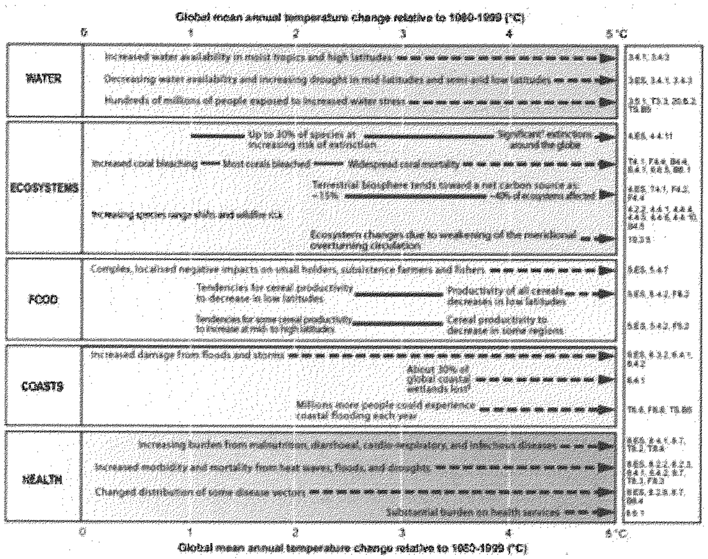
Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land-use change, while those of methane and nitrous oxide are primarily due to agriculture.

The understanding of anthropogenic warming and cooling influences on climate has improved since the Third Assessment Report (TAR), leading to very high confidence that the globally averaged net effect of human activities since 1750 has been one of warming, with a radiative forcing of +1.6 [+0.6 to +2.4] W m⁻².

Radiative Forcing Components



WMO INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE UNEP



Key impacts as a function of increasing global average temperature change

Working Group II

Illustrative examples of global impacts are projected for climate changes (and sea-level and atmospheric carbon dioxide where relevant) associated with different amounts of increase in global average surface temperature in the 21st century.

The black lines link impacts, dotted arrows indicate impacts continuing with increasing temperature. Entries are placed so that the left hand side of text indicates approximate onset of a given impact. Quantitative entries for water scarcity and flooding represent the additional impacts of climate change relative to the conditions projected across the range of Special Report on Scenarios (SRES) scenarios A1FI, A2, B1 and B2.

Adaptation to climate change is not included in these estimations. All entries are from published studies recorded in the chapters of the Assessment. Sources are given in the right hand column of the Table. Confidence levels for all statements are high.

Mitigation of Climate Change Working Group III

Sector	Key mitigation technologies and practices currently commercially available.	Key mitigation technologies and practices projected to be commercialized before 2030.
Energy Supply [4.3, 4.4]	Improved supply and distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy); combined heat and power; early applications of CCS (e.g. storage of removed CO_2 from natural gas)	Carbon Capture and Storage (CCS) for gas, biomass and coal-fired electricity generating facilities; advanced nuclear power; advanced renewable energy, including tidal and waves energy, concentrating solar, and solar PV
Transport [5.4]	More fuel efficient vehicles; hybrid vehicles; cleaner diesel vehicles; biofuels; model shifts from road transport to rail and public transport systems; non-motorised transports (cycling, walking); land-use and transport planning	Second generation biofuels; higher efficiency aircraft; advanced electric and hybrid vehicles with more powerful and reliable batteries
Buildings [6.5]	Efficient lighting and daylighting; more efficient electrical appliances and heating and cooling devices; improved cook stoves, improved insulations; passive and active solar design for heating and cooling; alternative refrigeration fluids, recovery and recycle of fluorinated gases	Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control; solar PV integrated in buildings
Industry [7.5]	More efficient end-use electrical equipment; heat and power recovery; material recycling and substitution; control of non-CO_2 gas emissions; and a wide array of process-specific technologies	Advanced energy efficiency; CCS for cement, ammonia, and iron manufacture; inert electrodes for aluminium manufacture
Agriculture [8.4]	Improved crop and grazing land management to increase soil carbon storage; restoration of cultivated peaty soils and degraded lands; improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions; improved nitrogen fertilizer application techniques to reduce N_2O emissions; dedicated energy crops to replace fossil fuel use; improve energy efficiency	Improvements of crops yields
Forestry/forests [9.4]	Afforestation; reforestation; forest management; reduced deforestation; harvested wood product management; use of forestry products for bioenergy to replace fossil fuel use	Tree species improvements to increase biomass productivity and carbon sequestration. Improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land use change
Waste [10.4]	Landfill methane recovery; waste incineration with energy recovery; composting of organic waste; controlled waste water treatment; recycling and waste minimization	Biocovers and biofilters to optimize CH_4 oxidation

WMO INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE UNEP

Mitigation of Climate Change Working Group III

A wide variety of national policies and instruments are available to governments to create the incentives for mitigation action. Their applicability depends on national circumstances and an understanding of their interactions, but experience from implementation in various countries and sectors shows there are advantages and disadvantages for any given instrument (high agreement, much evidence). Four main criteria are used to evaluate policies and instruments: environmental effectiveness, cost effectiveness, distributional effects including equity, and institutional feasibility.

General findings about the performance of policies are:

☐ **Integrating climate policies in broader development policies makes implementation and overcoming barriers easier.**

☐ **Regulations and standards generally provide some certainty about emission levels. They may be preferable to other instruments when information or other barriers prevent producers and consumers from responding to price signals. However, they may not induce innovations and more advanced technologies.**

☐ **Taxes and charges can set a price for carbon, but cannot guarantee a particular level of emissions. Literature identifies taxes as an efficient way of internalizing costs of GHG emissions.**

☐ **Tradable permits will establish a carbon price. The volume of allowed emissions determines their environmental effectiveness, while the allocation of permits has distributional consequences. Fluctuation in the price of carbon makes it difficult to estimate the total cost of complying with emission permits.**

☐ **Financial incentives (subsidies and tax credits) are frequently used by governments to stimulate the development and diffusion of new technologies. While economic costs are generally higher than for the instruments listed above, they are often critical to overcome barriers.**

☐ **Voluntary agreements between industry and governments are politically attractive, raise awareness among stakeholders, and have played a role in the evolution of many national policies. The majority of agreements has not achieved significant emissions reductions beyond business as usual. However, some recent agreements, in a few countries, have accelerated the application of best available technology and led to measurable emission reductions.**

☐ **Information instruments (e.g. awareness campaigns) may positively affect environmental quality by promoting informed choices and possibly contributing to behavioural change, however, their impact on emissions has not been measured yet.**

☐ **RD&D can stimulate technological advances, reduce costs, and enable progress toward stabilization.**

Global Warming Debate: Skepticism persists but science has improved

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Comments below courtesy Wikipedia, The Free Encyclopedia

Material excerpted from entry titled "Global cooling" available at http://en.wikipedia.org/wiki/Global_cooling#_note-16

Wikipedia's informative entry titled "Global warming" available at http://en.wikipedia.org/wiki/Global_warming

1975 Newsweek article

April 28, 1975 article in Newsweek magazine. Titled "The Cooling World," it pointed to "ominous signs that the Earth's weather patterns have begun to change" and pointed to "a drop of half a degree [Fahrenheit] in average ground temperatures in the Northern Hemisphere between 1945 and 1968." The article claimed "The evidence in support of these predictions [of global cooling] has now begun to accumulate so massively that meteorologists are hard-pressed to keep up with it." The Newsweek article did not state the cause of cooling; it stated that "what causes the onset of major and minor ice ages remains a mystery" and cited the NAS conclusion that "not only are the basic scientific questions largely unanswered, but in many cases we do not yet know enough to pose the key questions."

The article mentioned the alternative solutions of "melting the Arctic ice cap by covering it with black soot or diverting arctic rivers" but conceded these were not feasible. The Newsweek article concluded by criticizing government leaders: "But the scientists see few signs that government leaders anywhere are even prepared to take the simple measures of stockpiling food or of introducing the variables of climatic uncertainty into economic projections of future food supplies...The longer the planners (politicians) delay, the more difficult will they find it to cope with climatic change once the results become grim reality." The article emphasized sensational and largely unsourced consequences - "resulting famines could be catastrophic", "drought and desolation," "the most devastating outbreak of tornadoes ever recorded", "droughts, floods, extended dry spells, long freezes, delayed monsoons," "impossible for starving peoples to migrate," "the present decline has taken the planet about a sixth of the way toward the Ice Age."

On October 23, 2006, Newsweek issued a correction, over 31 years after the original article, stating that it had been "so spectacularly wrong about the near-term future" (though editor Jerry Adler claimed that the article was not "inaccurate" in a journalistic sense).

Present level of knowledge

Thirty years later, the concern that the cooler temperatures would continue, and perhaps at a faster rate, can now be observed to have been incorrect. More has to be learned about climate, but the growing records have shown the cooling concerns of 1975 to have been simplistic and not borne out.

Climate science has improved

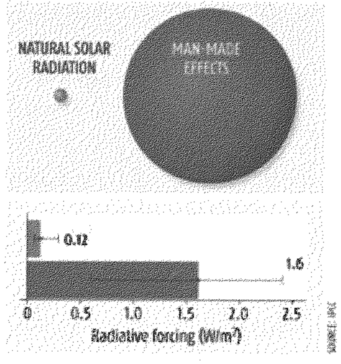
Scientific knowledge regarding climate change was more uncertain [in the 1970s] than it is today. At the time that Rasool and Schneider wrote their paper (published in the journal *Science* in July 1971), climatologists had not yet recognized the significance of greenhouse gases other than water vapor and carbon dioxide, such as methane, nitrous oxide and chlorofluorocarbons. Early in that decade, carbon dioxide was the only widely studied human-influenced greenhouse gas. The attention drawn to atmospheric gases in the 1970s stimulated many discoveries in future decades. As the temperature pattern changed, global cooling was of waning interest by 1979.

The Solar Effect

NewScientist

THE SUN VERSUS HUMANS

Amount of radiation (or heat) entering the Earth's climate system, known as radiative forcing



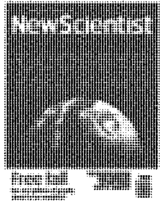
Note: The "circles" graphic is an amended version of the original appearing in *NewScientist* – to show the estimated contributions as equal areas and not equal diameters.

It is one of the few areas where the sceptics' argument has had some force. What role has the sun played in recent climate change? As if to underline the controversy, [the IPCC] debate on this issue lasted some 10 hours.

The scientists wanted to halve their previous estimate of the maximum possible solar influence on warming over the past 250 years, from 40 percent to 20 percent. Government delegations from China and Saudi Arabia refused to accept that, based on new ideas about cosmic rays from outer space.

Cosmic rays ionise the atmosphere, which could, the theory goes, create clouds. Thus, anything that reduces the amount of cosmic rays could diminish cloud cover and so warm the Earth's surface. An increase in solar activity would do just that - by deflecting cosmic rays away from Earth. China and Saudi Arabia were buoyed by claims that small changes in radiation from the sun could be amplified by their potential effect on clouds. Thus, they said, the sun could have a greater effect than the scientists claimed.

Most climate scientists are unconvinced. "Right now there is no evidence," says IPCC author Piers Forster of the University of Leeds, UK. In any case, IPCC scientists believe, most of today's warming can be explained by man-made influences (see Charts). But with a book due from solar-radiation proponent Henrik Svensmark of the Danish National Space Center, this may not be the end of the matter.



Source: *NewScientist magazine*, 10 February 2007

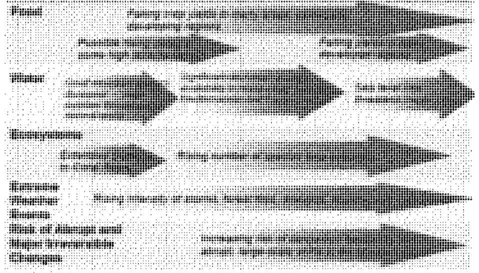
Website: http://www.newscientist.com

Stern Review on The Economics of Climate Change

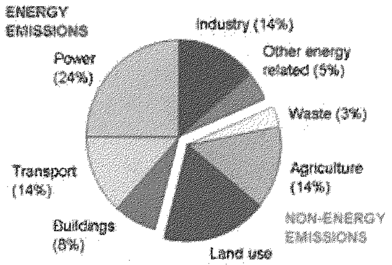
- There is still time to avoid the worst impacts of climate change, if we take strong action now.
- Climate change could have very serious impacts on growth and development.
- The costs of stabilising the climate are significant but manageable; delay would be dangerous and much more costly.
- Action on climate change is required across all countries, and it need not cap the aspirations for growth of rich or poor countries.
- A range of options exists to cut emissions; strong, deliberate policy action is required to motivate their take-up.
- Climate change demands an international response, based on a shared understanding of long-term goals and agreement on frameworks for action.

Website:
http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm

Projected Impacts of Climate Change



Global Emissions by Sector



Total emissions in 2000: 42 GtCO2e

Stern Review on The Economics of Climate Change

Key elements of future international frameworks should include:

- **Establishing a carbon price, through tax, trading or regulation is an essential foundation for climate change policy**
- **Emissions trading:** Expanding and linking the growing number of emissions trading schemes around the world is a powerful way to promote cost-effective reductions in emissions and to bring forward action in developing countries. Strong targets in rich countries could drive flows amounting to tens of billions of dollars each year to support the transition to low-carbon development paths.
- **Technology cooperation:** Informal co-ordination as well as formal agreements can boost the effectiveness of investments in innovation around the world. Globally, support for energy R&D should at least double, and support for the deployment of new low-carbon technologies should increase up to five-fold. International cooperation on product standards is a powerful way to boost energy efficiency.
- **Action to reduce deforestation:** The loss of natural forests around the world contributes more to global emissions each year than the transport sector.
- **Curbing deforestation** is a highly cost-effective way to reduce emissions; large scale international pilot programmes to explore the best ways to do this could get underway very quickly.
- **Adaptation:** The poorest countries are most vulnerable to climate change. It is essential that climate change be fully integrated into development policy, and that rich countries honour their pledges to increase support through overseas development assistance. International funding should also support improved regional information on climate change impacts, and research into new crop varieties that will be more resilient to drought and flood.

GLOBAL ROUNDTABLE ON CLIMATE CHANGE

Global Roundtable on Climate Change

The Earth Institute
AT COLUMBIA UNIVERSITY

Statement Executive Summary

Climate change is an urgent problem requiring global action to reduce emissions of carbon dioxide (CO2) and other greenhouse gases (GHGs). Energy use is vital for a modern economy. Burning fossil fuels produces CO2. Thus, confronting climate change depends, in many ways, on adopting new and sustainable energy strategies that can meet growing global energy needs while allowing for the stabilization of atmospheric CO2 concentrations at safe levels.

- The world's governments should set scientifically informed targets, including an ambitious but achievable interim, mid-century target for global CO2 concentrations, for "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system," in accordance with the stated objective of the Framework Convention on Climate Change (UNFCCC).
- All countries should be party to this accord, which should include specific near- and long-term commitments for action in pursuit of the agreed targets. Commitments for actions by individual countries should reflect differences in levels of economic development and GHG emission patterns and the principles of equity and common but differentiated responsibilities.
- Clear, efficient mechanisms should be established to place a market price on carbon emissions that is reasonably consistent worldwide and across sectors in order to reward efficiency and emission avoidance, encourage innovation, and maintain a level playing field among possible technological options.
- Government policy initiatives should address energy efficiency and de-carbonization in all sectors, allow businesses to choose among a range of options as they strive to minimize GHG emissions and costs, encourage the development and rapid deployment of low-emitting and zero-emitting energy and transportation technologies, and provide incentives to reduce emissions from deforestation and harmful land management practices.
- Governments, the private sector, trade unions, and other sectors of civil society should undertake efforts to prepare for and adapt to the impacts of climate change, since climate change will occur even in the context of highly effective mitigation efforts.
- Signatories to this statement will support scientific processes including the Intergovernmental Panel on Climate Change (IPCC); work to increase public awareness of climate change risks and solutions; report information on their GHG emissions; engage in GHG emissions mitigation, which can include emissions trading schemes; champion demonstration projects; and support public policy efforts to mitigate climate change and its impacts.

Website: http://www.earthinstitute.columbia.edu/grocc/grocc4_statement.html

GLOBAL ROUNDTABLE ON CLIMATE CHANGE

Global Roundtable on Climate Change

The Earth Institute
AT COLUMBIA UNIVERSITY

Management:

Jeffrey Sachs: Chair, Global Roundtable on Climate Change; Director, The Earth Institute at Columbia University; Quetelet Professor of Sustainable Development and Professor of Health Policy and Management, Columbia University.

David Downie: Director, Global Roundtable on Climate Change. Associate Director, Graduate Program in Climate and Society. Dr. Downie's research focuses on the creation, content, and implementation of international environmental policy.

Kate Brash: Assistant Director, Global Roundtable on Climate Change, The Earth Institute at Columbia University

Lyndon Valicenti: Program Coordinator, Global Roundtable on Climate Change, The Earth Institute at Columbia University

In addition, the Earth Institute's full time events staff in information technology, communications and events-planning facilitates the day-to-day operations of the Roundtable and all Roundtable and Working Group meetings. To contact the Roundtable, please send email to grocc@ei.columbia.edu.

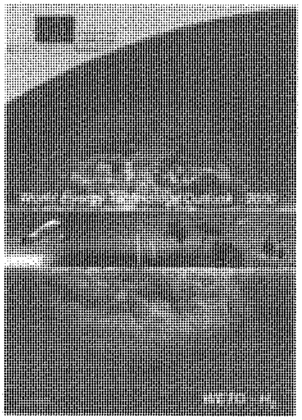
Released February 20, 2007

The Path to Climate Sustainability:
A Joint Statement by the Global Roundtable on Climate Change

The signatories include Air France, Alcoa, Allianz, American Electric Power, Bayer, China Renewable Energy Industry Association, Citigroup, DuPont, Electricity Generating Authority of Thailand, ENDESA, Eni, Eskom, FPL Group, General Electric, Iberdrola, ING, Interface, Marsh & McLennan Companies, Munich Re, NRG Energy, Patagonia, Ricoh, Rolls Royce, Stora Enso North America, Suntech Power, Swiss Re, Vattenfall, Volvo, World Council of Churches, World Petroleum Council, and many others.

European Commission

World Energy Technology Outlook - 2050



European Commission
Directorate-General for Research
Information and Communication Unit
B-1049 Brussels
Internet:
http://ec.europa.eu/research/energy/pdf/
weto-h2_en.pdf

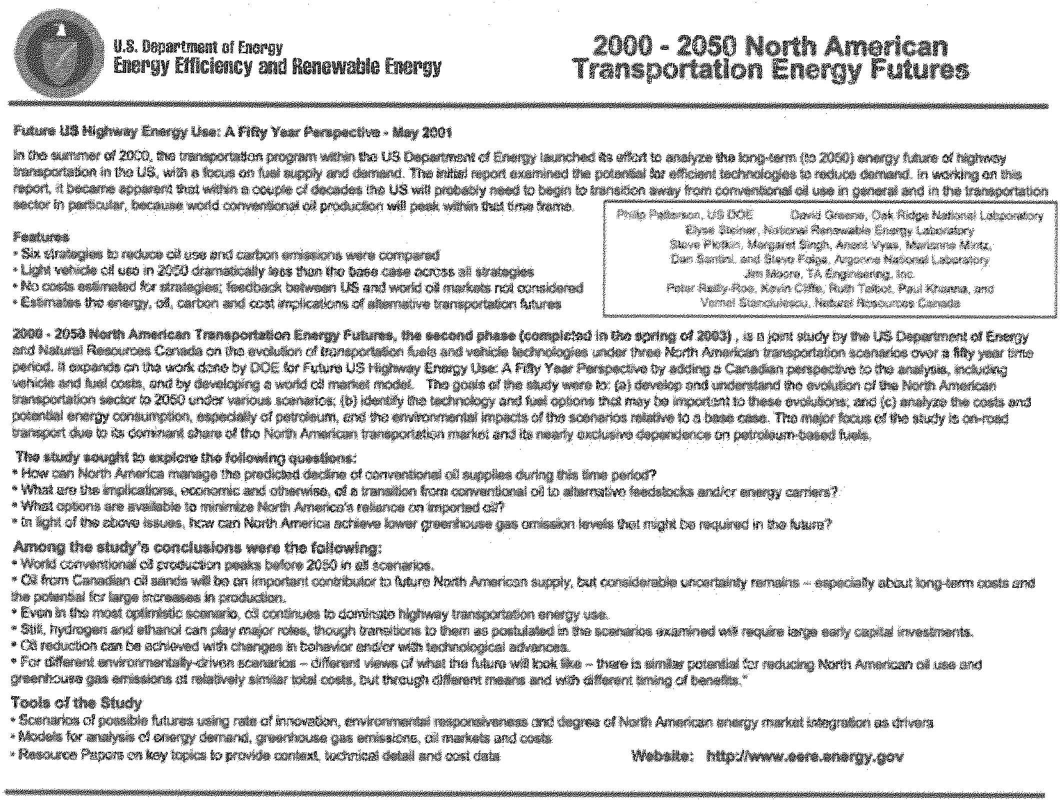
The WETO-H2 study has developed a Reference projection of the world energy system to test different scenarios for technology and climate policies in the next half-century. It has a particular focus on the diffusion of hydrogen as a fuel. This Reference projection adopts exogenous forecasts for population and economic growth in the different world regions and it makes consistent assumptions for the availability of fossil energy resources and for the costs and performances of future technologies. It uses a world energy sector simulation model – the POLES model – to describe the development to 2050 of the national and regional energy systems and of their interactions through international energy markets, under constraints on resources and from climate policy.

Conclusions

- In the Reference Case, by 2050 the "size" of the world energy system and corresponding CO2 emissions will be twice that of today.
- Relative scarcity of oil and gas ("plateau"): Coal comes to be increasingly the swing primary source in the world energy balance, which aggravates the problem raised by the energy-related CO2 emissions.
- Two alternative policy scenarios have been elaborated: A "Carbon Constraint Case" (CCC) and the "Hydrogen Scenario" (H2).
- The CCC scenario expects a very high carbon value (up to 200 €/tCO2 for Europe by 2050) to achieve a "factor two" reduction of emissions in the industrialised countries and progressive efforts from developing countries in order to get a stabilisation of emissions. In the CCC, there is important penetration of: (1) Carbon capture and storage (50% of thermal electricity in Europe), (2) Nuclear and renewables (75% of electricity), and (3) Low and very low energy buildings and vehicles (40%).
- The H2 scenario assumes technological breakthroughs in clusters of technologies concerning hydrogen production, distribution, storage, and end-use technologies. It has a substantial impact on transportation since by 2050 nearly 30% of total passenger cars run on hydrogen.

Annex

- Mean-variance portfolio (MVP) theory can help provide new insights to energy investment strategies. It demonstrates the range of possible mixes with technology shares that are +/- 20% from the POLES Reference. This enables policy makers to compare alternative 2050 outcomes, which may present more desirable CO2, energy diversity and other characteristics.
- The challenge of this research has been to merge the technically rich descriptive power of POLES with the ability of portfolio analysis to trade-off risk and reward. Optimisation identifies portfolios with better balances of cost and risk and other improved characteristics.
- The optimised mixes show improvements that may be attainable and which lie within close to the Reference. The remaining challenge is to identify policy changes that produce such optimised outcomes, a task to which the POLES simulation is ideally suited.



U.S. Department of Energy
Energy Efficiency and Renewable Energy

2000 - 2050 North American Transportation Energy Futures

Future US Highway Energy Use: A Fifty Year Perspective - May 2001

In the summer of 2000, the transportation program within the US Department of Energy launched its effort to analyze the long-term (to 2050) energy future of highway transportation in the US, with a focus on fuel supply and demand. The initial report examined the potential for efficient technologies to reduce demand. In working on this report, it became apparent that within a couple of decades the US will probably need to begin to transition away from conventional oil use in general and in the transportation sector in particular, because world conventional oil production will peak within that time frame.

Philip Patterson, US DOE David Greene, Oak Ridge National Laboratory
Elyse Steiner, National Renewable Energy Laboratory
Steve Plotkin, Margaret Singh, Anant Vyas, Marianne Mintz,
Dan Santini, and Steve Folga, Argonne National Laboratory
Jim Moore, TA Engineering, Inc.
Peter Reilly-Roe, Kevin Cliffe, Ruth Talbot, Paul Khanna, and
Vernel Stanciulescu, Natural Resources Canada

Features
- Six strategies to reduce oil use and carbon emissions were compared
- Light vehicle oil use in 2050 dramatically less than the base case across all strategies
- No costs estimated for strategies; feedback between US and world oil markets not considered
- Estimates the energy, oil, carbon and cost implications of alternative transportation futures

2000 - 2050 North American Transportation Energy Futures, the second phase (completed in the spring of 2003), is a joint study by the US Department of Energy and Natural Resources Canada on the evolution of transportation fuels and vehicle technologies under three North American transportation scenarios over a fifty year time period. It expands on the work done by DOE for Future US Highway Energy Use: A Fifty Year Perspective by adding a Canadian perspective to the analysis, including vehicle and fuel costs, and by developing a world oil market model. The goals of the study were to: (a) develop and understand the evolution of the North American transportation sector to 2050 under various scenarios; (b) identify the technology and fuel options that may be important to these evolutions; and (c) analyze the costs and potential energy consumption, especially of petroleum, and the environmental impacts of the scenarios relative to a base case. The major focus of the study is on-road transport due to its dominant share of the North American transportation market and its nearly exclusive dependence on petroleum-based fuels.

The study sought to explore the following questions:
- How can North America manage the predicted decline of conventional oil supplies during this time period?
- What are the implications, economic and otherwise, of a transition from conventional oil to alternative feedstocks and/or energy carriers?
- What options are available to minimize North America's reliance on imported oil?
- In light of the above issues, how can North America achieve lower greenhouse gas emission levels that might be required in the future?

Among the study's conclusions were the following:
- World conventional oil production peaks before 2050 in all scenarios.
- Oil from Canadian oil sands will be an important contributor to future North American supply, but considerable uncertainty remains – especially about long-term costs and the potential for large increases in production.
- Even in the most optimistic scenario, oil continues to dominate highway transportation energy use.
- Still, hydrogen and ethanol can play major roles, though transitions to them as postulated in the scenarios examined will require large early capital investments.
- Oil reduction can be achieved with changes in behavior and/or with technological advances.
- For different environmentally-driven scenarios – different views of what the future will look like – there is similar potential for reducing North American oil use and greenhouse gas emissions at relatively similar total costs, but through different means and with different timing of benefits."

Tools of the Study
- Scenarios of possible futures using rate of innovation, environmental responsiveness and degree of North American energy market integration as drivers
- Models for analysis of energy demand, greenhouse gas emissions, oil markets and costs
- Resource Papers on key topics to provide context, technical detail and cost data

Website: http://www.eere.energy.gov

UNITED NATIONS FOUNDATION

SIGMA XI
THE SCIENTIFIC RESEARCH SOCIETY

Confronting Climate Change

CONFRONTING CLIMATE CHANGE
AVOIDING THE UNMANAGEABLE AND MANAGING THE UNAVOIDABLE

The United Nations Department of Economic and Social Affairs (DESA) seeks to facilitate contributions by the scientific community to the work of the UN Commission on Sustainable Development. Accordingly, DESA invited Sigma Xi, the Scientific Research Society, to convene an international panel of scientific experts to prepare a report outlining the best measures for mitigating and adapting to global warming for submission to the CSD. The UN Foundation was funded by the Turner Gift.

To carry out this task, the Scientific Expert Group on Climate Change and Sustainable Development (SEG) was formed and is comprised of 18 distinguished international scientists. The panel was asked to consider innovative approaches for mitigating and/or adapting to projected climate changes, and to anticipate the relationship of response measures to sustainable development.

Website: http://www.unfoundation.org/SEG

Highlights of the resulting report include:

To avoid a entering a regime of sharply rising danger of intolerable impacts on humans, policy makers should limit temperature increases from global warming to 2-2.5°C above the 1750 pre-industrial level. It is still possible to avoid unmanageable changes in the future, but the time for action is now. Avoiding temperature increases greater than 2-2.5°C would require very rapid success in reducing emissions of methane and black soot worldwide, and global carbon dioxide emissions must level off by 2015 or 2020 at not much above their current amount, before beginning a decline to no more than a third of that level by 2100.

• **The technology exists to seize significant opportunities around the globe to reduce emissions and provide other economic, environmental and social benefits**, including meeting the United Nations' Millennium Development Goals. To do so, policy makers must immediately act to reduce emissions by: (1) Improving efficiency in the transportation sector through measures such as vehicle efficiency standards, fuel taxes, and registration fees/rebates that favor purchase of efficient and alternative fuel vehicles. (2) Improving design and efficiency of commercial and residential buildings through building codes, standards for equipment and appliances, incentives for property developers and landlords to build and manage properties efficiently, and financing for energy-efficiency investments. (3) Expanding the use of biofuels through energy portfolio standards and incentives to growers and consumers. (4) Beginning immediately, designing and deploying only coal-fired power plants that will be capable of cost-effective and environmentally-sound retrofits for capture and sequestration of their carbon emissions.

• **Some level of climate change and impacts from it is already unavoidable.** Societies must do more to adapt to ongoing and unavoidable changes in the Earth's climate system by: (5) Improving preparedness/response strategies and management of natural resources to cope with future climatic conditions that will be fundamentally different than those experienced for the last 100 years. (6) Addressing the adaptation needs of the poorest and most vulnerable nations, which will bear the brunt of climate change impacts. (7) Planning and building climate resilient cities. (8) Strengthening international, national, and regional institutions to cope with weather-related disasters and an increasing number of climate change refugees.

• **The international community, through the UN and related multilateral institutions, can play a crucial role in advancing action to manage the unavoidable and avoid the unmanageable by:** (9) Helping developing countries and countries with economies in transition to finance and deploy energy efficient and new energy technologies. 10) Accelerating negotiations to develop a successor international framework for addressing climate change and sustainable development. (11) Educating all about the opportunities to adopt mitigation and adaptation measures.

National Security and the Threat of Climate Change

The CNA Corporation

Global climate change presents a serious national security threat which could impact Americans at home, impact United States military operations and heighten global tensions, according to a new study released by a blue-ribbon panel of retired admirals and generals from all branches of the armed services.

The CNA Corporation (CNA) is a non-profit organization that provides research and analysis to inform public sector leaders. CNA brought together eleven retired senior admirals and generals to provide advice, expertise and perspective on the impact of climate change. CNA writers and researchers compiled the report under the board's direction and review. The study, "National Security and the Threat of Climate Change," explores ways projected climate change is a threat multiplier in already fragile regions, exacerbating conditions that lead to failed states — the breeding grounds for extremism and terrorism.

FINDINGS

- Projected climate change poses a serious threat to America's national security
- Climate change acts as a threat multiplier for instability in some of the most volatile regions of the world
- Projected climate change will add to tensions even in stable regions of the world
- Climate change, national security and energy dependence are a related set of global challenges

RECOMMENDATIONS

- The national security consequences of climate change should be fully integrated into national security and national defense strategies.
- The US should commit to a stronger national and international role to help stabilize climate changes at levels that will avoid significant disruption to global security and stability.
- The US should commit to global partnerships that help less developed nations build the capacity and resiliency to better manage climate impacts.
- The Department of Defense should enhance its operational capability by accelerating the adoption of improved business processes and innovative technologies that result in improved US combat power through energy efficiency.
- The Department of Defense should conduct an assessment of the impact on US military installations worldwide of rising sea levels, extreme weather events, and other possible climate change impacts over the next thirty to forty years.

Website: http://securityandclimate.cna.org

The Future of Coal

Massachusetts Institute of Technology

Leading academics from an interdisciplinary Massachusetts Institute of Technology (MIT) team issued a report that seeks to examine how the world can continue to use coal, an abundant and inexpensive fuel, in a way that mitigates, instead of worsens, the global warming crisis.

The goal of this MIT energy study, one of a series, was to evaluate the performance of different technologies, which in combination with policy and technology innovations, will reduce global emissions of CO2 and other greenhouse gases by mid-century.

Given that coal is likely to remain an important source of energy in any conceivable future energy scenario.

In particular, the focus is on carbon capture and sequestration (CCS) — the separation of the CO2 combustion product that is produced in conjunction with the generation of electricity from coal and the transportation of the separated CO2 to a site where the CO2 is sequestered from the atmosphere.

Website: http://web.mit.edu/coal/The_Future_of_Coal_Summary_Report.pdf

BOX 1 ILLUSTRATING THE CHALLENGE OF SCALE FOR CARBON CAPTURE

- Today fossil sources account for 80% of energy demand: Coal (25%), natural gas (21%), petroleum (34%), nuclear (6.5%), hydro (2.2%), and biomass and waste (11%). Only 0.4% of global energy demand is met by geothermal, solar and wind.[1]
- 50% of the electricity generated in the U.S. is from coal.[2]
- There are the equivalent of more than five hundred, 500 megawatt, coal-fired power plants in the United States with and average age of 35 years.[2]
- China is currently constructing the equivalent of two, 500 megawatt, coal-fired power plants per week in a capacity comparable to the entire UK power grid each year.[3]
- One 500 megawatt coal-fired power plant produces approximately 3 million tons/year of carbon dioxide (CO_2).[3]
- The United States produces about 1.5 billion tons per year of CO_2 from coal-burning power plants.
- If all of this CO_2 is transported from sequestration, the quantity is equivalent to three times the weight and, under typical operating conditions, one-third of the annual volume of natural gas transported by the U.S. gas pipeline system.
- If 60% of the CO_2 produced from U.S. coal-based power generation were to be captured and compressed to a liquid for geologic sequestration, its volume would about equal the total U.S. oil consumption of 20 million barrels per day.
- At present the largest sequestration project is injecting one million tons/year of carbon dioxide (CO_2) from the Sleipner gas field into a saline aquifer under the North Sea.[3]

1 IEA Key World Statistics (2006)
2 EIA 2005 annual statistics (www.eia.doe.gov)
3 Derived from the MIT Coal Study

The Future of Coal

Massachusetts Institute of Technology

Key Findings

* Coal is a low-cost, per BTU, mainstay of both the developed and developing world, and its use is projected to increase. Because of coal's high carbon content, increasing use will exacerbate the problem of climate change unless coal plants are deployed with very high efficiency and large scale CCS is implemented.

* CCS is the critical enabling technology because it allows significant reduction in CO2 emissions while allowing coal to meet future energy needs.

Table 1 Exajoules of Coal Use (EJ) and Global CO_2 Emissions (Gt/yr) in 2000 and 2050 with and without Carbon Capture and Storage*

	BUSINESS AS USUAL		LIMITED NUCLEAR 2050		EXPANDED NUCLEAR 2050	
	2000	2050	WITH CCS	WITHOUT CCS	WITH CCS	WITHOUT CCS
Coal Use: Global	100	448	161	116	121	78
U.S.	24	58	40	28	25	13
China	27	88	39	24	31	17
Global CO_2 Emissions	24	62	28	32	26	29
CO_2 Emissions from Coal	9	32	5	9	3	6

* Universal, simultaneous participation, High CO_2 prices and EPPA-Ref gas prices.

* A significant charge on carbon emissions is needed in the relatively near term to increase the economic attractiveness of new technologies that avoid carbon emissions and specifically to lead to large-scale CCS in the coming decades. We need large-scale demonstration projects of the technical, economic and environmental performance of integrated CCS systems.

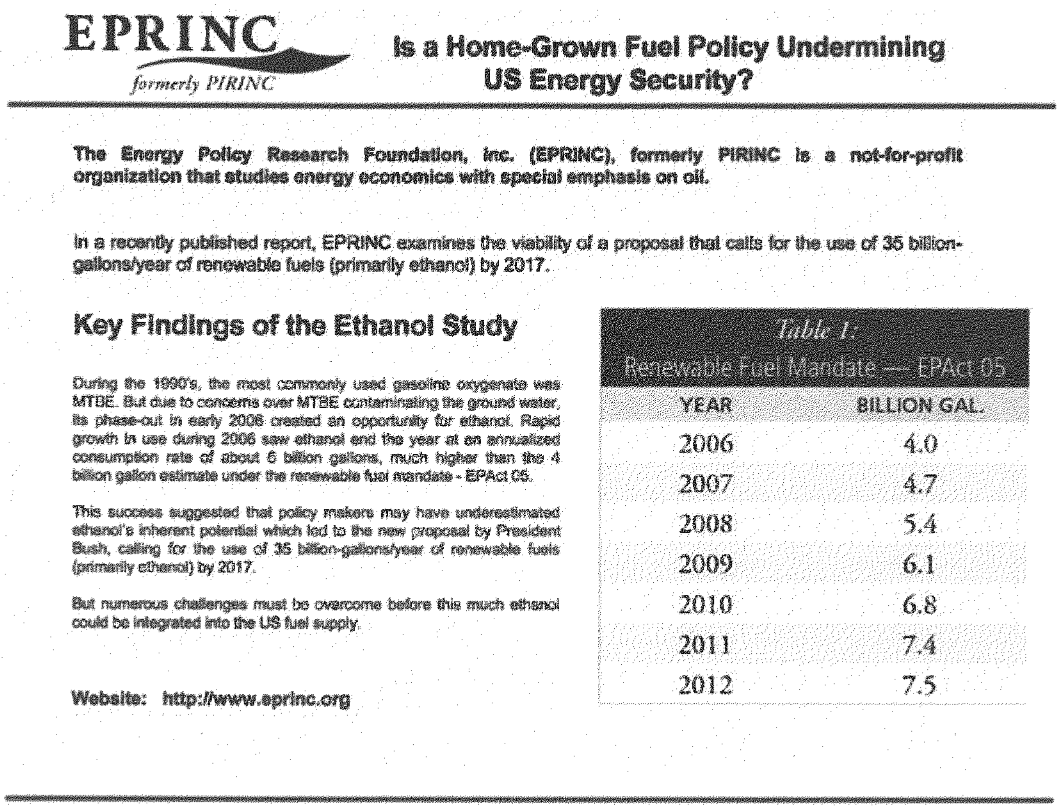
* The U.S. government should provide assistance only to coal projects with CO2 capture in order to demonstrate technical, economic and environmental performance.

* Today, IGCC appears to be the economic choice for new coal plants with CCS. However, this could change with further RD&D, so it is not appropriate to pick a single technology winner at this time, especially in light of the variability in coal type, access to sequestration sites, and other factors. The government should provide assistance to several "first of a kind" coal utilization demonstration plants, but only with carbon capture.

* Congress should remove any expectation that construction of new coal plants without CO2 capture will be "grandfathered" and granted emission allowances in the event of future regulation. This is a perverse incentive to build coal plants without CO2 capture today.

* Emissions will be stabilized only through global adherence to CO2 emission constraints. China and India are unlikely to adopt carbon constraints unless the U.S. does so and leads the way in the development of CCS technology.

* Key changes must be made to the current Department of Energy RD&D program to successfully promote CCS technologies.



EPRINC

formerly PIRINC

Is a Home-Grown Fuel Policy Undermining US Energy Security?

The Energy Policy Research Foundation, Inc. (EPRINC), formerly PIRINC is a not-for-profit organization that studies energy economics with special emphasis on oil.

In a recently published report, EPRINC examines the viability of a proposal that calls for the use of 35 billion-gallons/year of renewable fuels (primarily ethanol) by 2017.

Key Findings of the Ethanol Study

During the 1990's, the most commonly used gasoline oxygenate was MTBE. But due to concerns over MTBE contaminating the ground water, its phase-out in early 2006 created an opportunity for ethanol. Rapid growth in use during 2006 saw ethanol end the year at an annualized consumption rate of about 6 billion gallons, much higher than the 4 billion gallon estimate under the renewable fuel mandate - EPAct 05.

This success suggested that policy makers may have underestimated ethanol's inherent potential which led to the new proposal by President Bush, calling for the use of 35 billion-gallons/year of renewable fuels (primarily ethanol) by 2017.

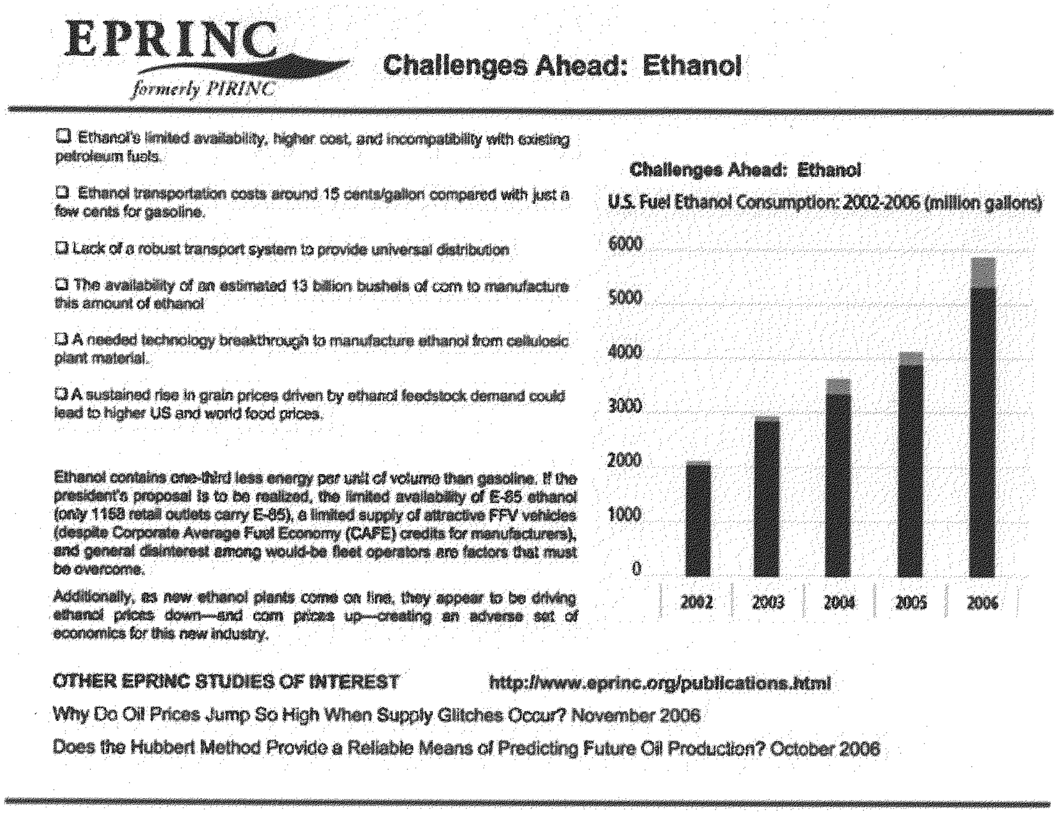
But numerous challenges must be overcome before this much ethanol could be integrated into the US fuel supply.

Table 1:

Renewable Fuel Mandate — EPAct 05

YEAR	BILLION GAL.
2006	4.0
2007	4.7
2008	5.4
2009	6.1
2010	6.8
2011	7.4
2012	7.5

Website: http://www.eprinc.org



EPRINC
formerly PIRINC

Challenges Ahead: Ethanol

☐ Ethanol's limited availability, higher cost, and incompatibility with existing petroleum fuels.

☐ Ethanol transportation costs around 15 cents/gallon compared with just a few cents for gasoline.

☐ Lack of a robust transport system to provide universal distribution

☐ The availability of an estimated 13 billion bushels of corn to manufacture this amount of ethanol

☐ A needed technology breakthrough to manufacture ethanol from cellulosic plant material.

☐ A sustained rise in grain prices driven by ethanol feedstock demand could lead to higher US and world food prices.

Challenges Ahead: Ethanol

U.S. Fuel Ethanol Consumption: 2002-2006 (million gallons)

Ethanol contains one-third less energy per unit of volume than gasoline. If the president's proposal is to be realized, the limited availability of E-85 ethanol (only 1158 retail outlets carry E-85), a limited supply of attractive FFV vehicles (despite Corporate Average Fuel Economy (CAFE) credits for manufacturers), and general disinterest among would-be fleet operators are factors that must be overcome.

Additionally, as new ethanol plants come on line, they appear to be driving ethanol prices down—and corn prices up—creating an adverse set of economics for this new industry.

OTHER EPRINC STUDIES OF INTEREST **http://www.eprinc.org/publications.html**

Why Do Oil Prices Jump So High When Supply Glitches Occur? November 2006

Does the Hubbert Method Provide a Reliable Means of Predicting Future Oil Production? October 2006

USCAP
United States
Climate Action
Partnership

US Climate Action Partnership

Six Design Principles

Account for the global dimensions of climate change

Create incentives for technology innovation

Be environmentally effective

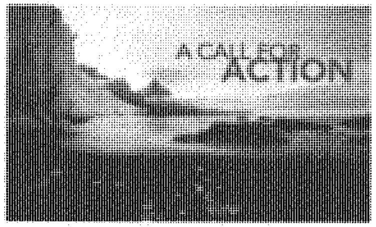
Create economic opportunity and advantage

Be fair to sectors disproportionately impacted

Reward early action

Website: http://www.us-cap.org

United States Climate Action Partnership (USCAP) is a group of businesses and leading environmental organizations that have come together to call on the federal government to quickly enact strong national legislation to require significant reductions of greenhouse gas emissions. USCAP has issued a landmark set of principles and recommendations to underscore the urgent need for a policy framework on climate change.



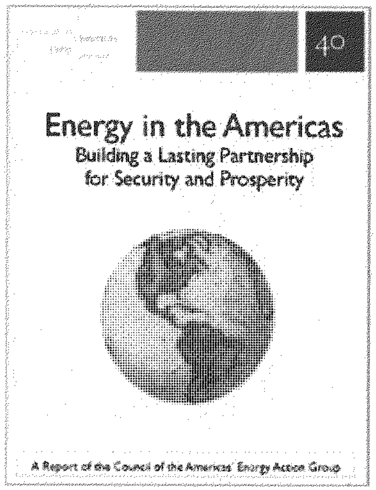
USCAP Members Include: Alcan Inc., Alcoa, American International Group, Inc., Boston Scientific Corporation, BP America Inc., Caterpillar Inc., Chrysler Group, ConocoPhillips, Deere & Company, The Dow Chemical Company, Duke Energy, DuPont, Environmental Defense, Ford Motor Company, FPL Group, Inc., General Electric, General Motors Corp., Johnson & Johnson, Marsh, Inc., National Wildlife Federation, Natural Resources Defense Council, The Nature Conservancy, NRG Energy, Inc., PepsiCo, Pew Center on Global Climate Change, PG&E Corporation, PNM Resources, Shell, Siemens Corporation, World Resources Institute, Xerox Corporation.

USCAP offers the following interconnected set of recommendations for the general structure and key elements of climate protection legislation that we urge Congress to enact as quickly as possible. The legislation should require actions to be implemented on a fast track while a cap and trade program is put in place. We recommend these fast track actions begin within one year of enactment.

- ➢ Take a stepwise cost-effective approach
- ➢ Cap and Trade is essential
- ➢ Establish short and mid-term GHG emission targets
- ➢ GHG inventory and registry
- ➢ Credit for early action
- ➢ Aggressive technology research and development
- ➢ Policies to discourage new investments in high-emitting facilities
- ➢ Accelerated deployment of zero and low-emitting technologies and energy efficiency

Council of the Americas

Energy Action Group



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Energy in the Americas

Building a Lasting Partnership for Security and Prosperity

A Report of the Council of the Americas' Energy Action Group

The Energy Action Group works to identify financial, macroeconomic, industry and business specific issues of concern and solutions. It addresses the security of the energy supply; improvement of the investment climate for energy and development; North American energy integration; energy supply to the region; and alternative energy sources such as Liquefied Natural Gas. As a key part of this initiative, the Council of the Americas leads ongoing discussions with diplomats, visiting dignitaries and senior policy officials to create an open forum for energy issues.

Energy Action Group Themes:

Security of Energy Supply — Oil and gas supplies in the Western Hemisphere are very important to the United States and the region. Current political situations in several countries make this a crucial and on-going issue.

Energy Industry Investment Issues — Topics including investment climate safety, security of commitments, and investment dispute resolution will be discussed.

North American Energy Integration — We are working to advance the North American energy integration dialogue, in conjunction with the Mexico-US (MEXUS) Business Committee, a committee of the Council of the Americas. Through MEXUS, we bring together energy companies of NAFTA countries to promote one agenda to policy makers.

Supplying Energy to the Region — As industrialization continues in the Western Hemisphere, there will be a larger demand for reliable production and transmission of electricity. Historically, energy consumption increases at twice the rate of GDP growth. If this trend continues, the region's largest economies will not be able to meet demand.

Alternate Energy Sources — As the United States and the rest of the Western Hemisphere look to broaden their energy sources, they have begun to look at alternative sources of power. Among them are Liquefied Natural Gas (LNG), Hydroelectric Power, and Solar Energy.

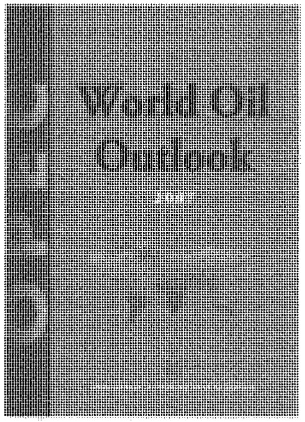
Setting An Agenda — EAG members play an active role in setting the agenda for the group. By keeping the Council and the rest of the EAG informed of current issues, we are working together to promote discussion, advancement, and favorable resolutions.

Website:
http://www.counciloftheamericas.org/

http://www.americas-society.org/coa/events/2006events/2005/October/EnergyReport/FINAL%20-%20COA%20Energy%20Action%20Group%20Report.pdf

OPEC ORGANIZATION OF THE PETROLEUM EXPORTING COUNTRIES

World Oil Outlook 2007



- **The OPEC Secretariat** has, for many years, produced a medium- to long-term outlook of the global oil scene. Results and analysis have offered insights into many important issues that producing countries and the oil industry have been, and may be confronted with in the future.

- In our reference case, with an average global economic growth rate of 3.5% per annum (purchasing power parity basis), and oil prices assumed to remain in the $50-60/b range in nominal terms for much of the projection period, oil demand is set to rise from the 2005 level of 83 mb/d to 118 mb/d by 2030. This also assumes that no particular departure in trends for energy policies and technologies takes place. This is a very important caveat for there are inherent downside risks to demand, something that is specifically addressed in this outlook.

- The transportation sector will be the main source of future oil demand increases. Of the non-transportation oil use, the main expected source of increase will be in the industrial and residential sectors of developing countries, which see a combined growth to 2030 of over 11 mboe/d in the reference case.

- Initial increases in both crude and non-crude supply pushes total non-OPEC supply up to 54 mb/d in 2010. This is 5 mb/d higher than in 2005. After 2010, non-OPEC crude supply, including NGLs, stabilises, then eventually falls. Yet with non-conventional oil supply increasing at strong rates, over the entire projection period, total non-OPEC supply actually continues to rise.

- The amount of crude oil supply expected from OPEC increases post-2010, rising, in this reference case, to 38 mb/d by 2020 and 49 mb/d by 2030.

- There is a great deal of uncertainty over future demand and non-OPEC supply, which translates into large uncertainties over the amount of oil that OPEC Member Countries will eventually need to supply. Investment requirements are very large, and subject to considerably long lead-times and pay-back periods. It is therefore essential to explore these uncertainties in the context of alternative scenarios.

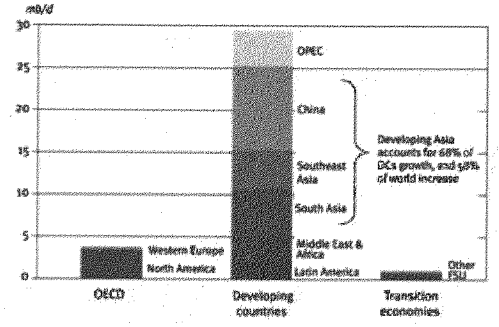
- Taking into account the most likely changes in the future supply and demand structures and their quality specifications, the global downstream sector will require in the period 2006–2020, 13 mb/d of additional distillation capacity, around 7.5 mb/d of combined upgrading capacity, 18 mb/d of desulphurisation capacity and 2 mb/d of capacity for other supporting processes, such as alkylation, isomerisation and reforming.

Website: http://www.opec.org/library/World%20Oil%20Outlook/pdf/WorldOilOutlook.pdf

OPEC ORGANIZATION OF THE PETROLEUM EXPORTING COUNTRIES

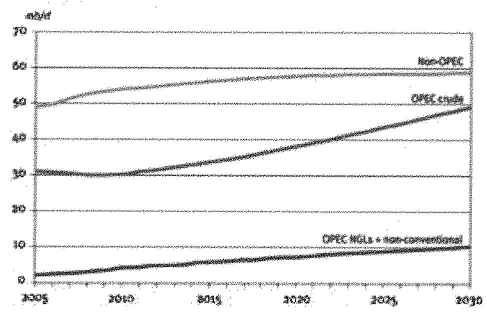
World Oil Outlook 2007

Annual growth in oil demand, 2005–2030



OECD countries, currently accounting for close to 60% of world oil demand, see a further growth of 4 mb/d by 2030, reaching 53 mb/d. Developing countries account for most of the rise in the reference case, with consumption doubling from 29 mb/d to 58 mb/d. Asian developing countries account for an increase of 20 mb/d, which represents more than two-thirds of the growth in all developing countries.

World oil supply, 2005–2030



Inter-regional oil trade should increase by 13 mb/d to almost 63 mb/d of oil exports in 2020. Both crude and products exports will increase appreciably, with products exports growing faster than crude oil exports. Correspondingly, the reference case outlook calls for a total tanker fleet requirement in 2020 of 460 million dwt. This compares to 360 million dwt as of the end of 2006.

ENERGY
CHARTER
SECRETARIAT

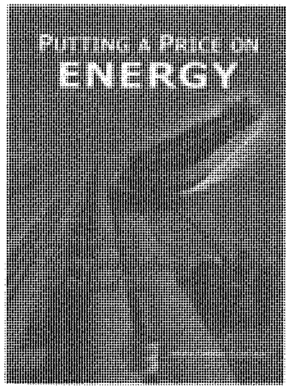
Putting a Price on Energy

International Pricing Mechanisms for Oil and Gas

The Energy Charter Treaty

The Energy Charter Treaty provides a multilateral framework for energy cooperation that is unique under international law. It is designed to promote energy security through the operation of more open and competitive energy markets, while respecting the principles of sustainable development and sovereignty over energy resources.

A core principle of the Energy Charter is 'market-oriented price formation' for the energy sector, within the framework of sovereign rights over energy resources. But this begs the question: how can these two elements be combined and how are they reflected in the formation of oil and gas prices in international trade?


PUTTING A PRICE ON
ENERGY

Overall Conclusions

Website: http://www.encharter.org

This report looks at the pricing mechanisms for oil and gas by also using approaches of some more specialised parts of economic theory, mainly transaction cost theory dealing with different pricing and contract mechanism of open markets, long-term contracts and vertical integration, the theory of finite resources as reflected in Hotelling and Ricardian rent and the principal-agent theory. They suggest the following analysis:

The transaction cost theory suggests that the combination of marketplaces, long-term contracts and vertical integration depends on technology, market structure and regulation, and that it will change to reflect their development. Geology and geography provide the overall context, but the impact of endowments changes with the development of technology, as well as of markets and regulations. An important element in order to understand differences in pricing mechanisms is that there are two actors on the supply side: the resource owner, usually represented by a national government, which takes decisions determining the depletion of its resources, and the producing company, which takes the decision to invest.

Oil has already been traded internationally for more than a century, and trade in oil has developed all the features of a global commodity market. However, natural gas has not (yet) followed suit, and whether and how a global gas market might emerge is a hotly debated topic in international energy.

What we see instead, in the case of natural gas, are strong variations in the pricing mechanisms for international gas trade into different regional and national markets. This study examines possible reasons for these differences, starting with the physical properties of natural gas and the distribution of gas reserves, and continuing with a detailed consideration of the mechanisms that have emerged to determine gas prices in North America, in the UK and in Continental Europe. It also examines the role of liquefied natural gas in providing a link between different markets.

The aim of this study is to encourage an informed debate about international oil and gas pricing, which itself is a key to understanding many current developments on international energy markets. The study, available on the Energy Charter's website, does not recommend a particular model for national energy markets or for international commercial arrangements. However, and particularly where gas is traded through pipelines, it underlines that the international gas trade depends on long-term decisions that are taken along the entire energy chain. This in turn strengthens the significance of the Energy Charter as an instrument for international energy cooperation, since the Charter establishes binding disciplines protecting these long-term investment and trade decisions.

APPENDIX E

ADDITIONAL MATERIALS ON THE CD

This appendix provides detailed descriptions of additional study materials contained on the CD included with the final printed version of the National Petroleum Council (NPC) report, *Facing the Hard Truths about Energy: A Comprehensive View to 2030 of Global Oil and Natural Gas.* The CD contains the following files:

- Final Report
- Report Glossary
- Report Slide Presentation
- Webcast of NPC Meeting and Press Conference
- Study Topic Papers
- Study Data Warehouse Files

The contents of the CD also can be viewed and downloaded from the NPC website (www.npc.org) and additional or replacement copies of the CD can be purchased from the same site.

FINAL REPORT

The final report, as approved by the members of the National Petroleum Council and submitted to Secretary Bodman, is included on the report's CD. This copy of the printed report is in PDF format, contains hyperlinks among sections, and is searchable using Adobe software. It provides the report sections as follows:

- Transmittal Letter to Secretary Bodman (2-page summary of report)
- Table of Contents
- Preface
- Executive Summary
- Report Chapters
  - Chapter One: Energy Demand
  - Chapter Two: Energy Supply
  - Chapter Three: Technology
  - Chapter Four: Geopolitics
  - Chapter Five: Carbon Management
  - Chapter Six: Recommendations
  - Chapter Seven: Methodology
- Appendices
  - Appendix A: Request Letter and Description of the NPC
  - Appendix B: Study Group Rosters
  - Appendix C: Study Outreach Process and Sessions
  - Appendix D: Parallel Studies Process and Summaries
  - Appendix E: Additional Materials on the CD
- Acronyms and Abbreviations

REPORT GLOSSARY

The report's CD contains a detailed glossary of terms used in the report, which was drawn almost in its entirety from a glossary provided by EIA. The glossary is provided in PDF format. The NPC is appreciative of EIA allowing the use of this document and assumes responsibility for any modifications that have been made to it.

REPORT SLIDE PRESENTATION

On July 18, 2007, a detailed slide presentation on the report, *Facing the Hard Truths about Energy,* was delivered to Secretary of Energy Samuel W. Bodman and the membership of the National Petroleum Council. This slide presentation is included on the report's CD to allow readers access to materials that were used to help explain the study process and results. Two versions are provided in PDF format:

- Slides only
- Slides with presenter's text as notes.

WEBCAST OF NPC MEETING AND PRESS CONFERENCE

The report's CD also contains a webcast of the July 18, 2007 NPC meeting as follows:

- Presentation on the report to the NPC membership
- Report approval and delivery to Secretary of Energy, Samuel W. Bodman
- Remarks by Secretary Bodman
- Press conference on July 18, 2007, following the NPC meeting.

STUDY TOPIC PAPERS

On July 18, 2007, the National Petroleum Council in approving its report, *Facing the Hard Truths about Energy,* also approved making available certain materials used in the study process, including detailed, specific subject matter papers prepared by the Task Groups and their Subgroups. These Topic Papers were part of the analyses that led to development of the summary results presented in the report's Executive Summary and Chapters. The final report's CD includes final versions of these papers.

These Topic Papers represent the views and conclusions of the authors. The National Petroleum Council has not endorsed or approved the statements and conclusions contained in these documents but approved the publication of these materials as part of the study process.

The NPC believes that these papers will be of interest to the readers of the report and will help them better understand the study results. These materials are being made available in the interest of transparency.

A list of these Topic Papers with brief abstracts for each follows.

Demand Task Group

Paper #1: Coal Impact ✦

The United States has the largest coal reserves in the world, followed by Russia and China. Coal now provides about a quarter of the energy used in the United States. The share of U.S. energy to be supplied by coal is projected to increase modestly to 2030. Coal use worldwide exhibits the same characteristics as in the United States. The largest increase in coal use through 2030 is projected to be in China, followed by the United States and India. Coal is consumed in large quantities throughout the United States, while most production is focused in a few states, requiring significant quantities of coal to be transported long distances. To that end, U.S. coal consumers and producers have access to the world's most comprehensive and efficient coal transportation system. The extent to which coal is able to help meet future U.S. energy challenges will depend heavily on the performance of coal transporters.

Paper #2: Cultural/Social/Economic Trends✦

Population and the economy are normally directly associated with projecting energy use trends, but other factors play an important role in understanding these trends. This topic paper examined 8 of these trends, which were thought to be the most significant. These trends include the relationship between the structural change in the economy and energy use, the importance of oil and natural gas to future energy use patterns, carbon dioxide emissions and their relationship to fossil-fuel use, China and its anticipated energy use growth, the energy use conundrum related to the introduction of new energy consuming technologies into the market place, the potential for energy use savings in the light-duty vehicle fleet, energy use and its association with energy price, and the impact of fuel-switching capability in the transportation sector.

Paper #3: Demand Data Evaluation ✦

This report contains the findings of the Demand Data Evaluation Subgroup of the Demand Task Group, which reviewed, analyzed, and compared projection data collected in the NPC data warehouse through surveys for both public and proprietary projections of world energy demand. Major "drivers" underpinning the demand projections are population and economy. In all cases, worldwide and U.S. energy demand is projected to increase. In a general sense, the worldwide increase in energy is expected to be about 60 percent by 2030, matching the worldwide increase over the last 25 years. Detailed analyses were conducted using input from the U.S. Energy Information Administration (EIA) and the International Energy Agency (IEA). Other public studies were less complete than those produced by the EIA and the IEA, but confirmed the observations made from those studies as did the aggregated proprietary data collection effort.

Paper #4: Electric Generation Efficiency ✦

Expected improvements in electric generation efficiency are projected to mainly come from the replacement of old plants with new plants that are constructed using contemporary technology with better efficiencies. Existing unit efficiency is not projected to improve significantly as replacement of auxiliary equipment is the only area where contemporary technology can be introduced. There are regional differences in the rate of improvement in electric generation efficiencies as developing regions have less installed capacity and are projected to add new electric generating capability at a faster rate than in industrialized regions.

Paper #5: Industrial Efficiency ✦

This topic paper examines industrial energy use trends, the potential impact of energy efficiency technologies, and barriers to their adoption. The industrial sector is a large and price-responsive energy consumer. Energy efficiency opportunities of 5 quadrillion Btu per year, or over 15 percent of industrial energy use, exist broadly across the industrial sector. While 40 percent of these opportunities could be captured using existing technology and systems, further research-and-development is required to implement the rest. Areas of opportunity include waste-heat recovery, separations, and combined heat and power. By providing fuel-switching capability, the industrial sector serves as a quickly responding buffer against supply or demand shocks. Unfortunately, industrial fuel-switching capability has decreased in recent years.

Paper #6: Residential Commercial Efficiency ✦

About 40 percent of U.S. energy is consumed in the residential and commercial sectors. If "achievable" cost-effective energy-efficiency measures were deployed, energy use in these two sectors could be rougbly 15-20 percent below that anticipated in a business-as-usual future. Most energy consumed in these sectors is for traditional uses such as heating, cooling and lighting. However, a growing portion is being used to power new devices, many of which were rare or even nonexistent just a few years ago. Significant efficiency improvements have been made in building shells, systems, and appliances. But these improvements have been offset to some extent by additional demand for energy services resulting from trends toward bigger structures, use of increasing numbers of traditional appliances, and introduction of new energy consuming devices. Buildings typically last decades if not centuries. Many of the features of buildings that affect their energy consumption largely will go unchanged throughout the life of the building. Technologies and practices affecting energy use in these long-lived systems will be slow to penetrate and affect overall efficiency.

Supply Task Group

Paper #7: Global Access to Oil and Gas ✦

For environmental and other policy reasons, governments around the world, including the U.S., have reduced access to oil and natural gas resources. This paper is a detailed description of resource types, locations, and volumes subject to U.S. federal access restrictions or moratoria. The paper also includes data about restricted global and North American access as well as oil and gas production from marginal U.S. wells.

Paper #8: Biomass ✦

Biomass is part of the global resource endowment for supplying energy. This paper is a detailed survey of biomass, particularly cultivated crops, as a source of both energy and food. The paper considers the range of estimates for energy supplied by biomass; agricultural capacity to meet projected fuel and food demands; and the conditions needed to optimize energy crop production, including bioengineered or genetically modified crops. It also discusses infrastructure considerations and second-generation conversion technologies needed to secure biomass as a significant source of energy supply.

Paper #9: Gas to Liquids (GTL) ✦

The term gas to liquids refers to technologies that convert natural gas to liquid fuels, as an alternative to refining crude oil and other commercialization paths for natural gas. Interest in large-scale GTL has grown over the past 10 years, based on strong demand for diesel fuel, particularly in Europe and Asia; increasingly stringent environmental specifications for diesel fuel; the commercial potential in monetizing stranded gas; and requirements to reduce flaring of natural gas and develop economic uses for the gas. This paper describes recent GTL developments and assesses potential capacity additions and commercial prospects.

Paper #10: Geologic Endowment ✦

The geologic endowment of oil, natural gas, coal, or other hydrocarbons is a fundamental consideration for energy policy. This paper defines the major types of hydrocarbons and essential concepts such as reserves and resources that are used in energy discussions. The paper discusses a wide range of global resource estimates, their underlying methodologies, and the challenges in making resource assessments. The discussion concludes with a call to update estimates of global hydrocarbon resources using best-practice assessment techniques.

Paper #11: Hydrogen ✦

Hydrogen is of great interest in the longer-term as the potential basis for a non-hydrocarbon energy economy. This paper describes the potential role of hydrogen at large scale in reducing U.S. petroleum imports and carbon emissions. The paper summarizes a range of estimates for hydrogen's share of energy supply through 2030 and beyond and discusses the R&D, distribution, and infrastructure requirements needed to make hydrogen a viable supply option.

Paper #12: Infrastructure ✦

Transportation infrastructure is a vast, complex network of pipelines, railways, waterways, and roads that deliver energy from sources of supply to points of demand. Much of the U.S. transportation system was in place by the 1970s. This paper concludes that the network is approaching a tipping point as aging infrastructure contends with growing and increasingly diversified demand. Fragmented or outdated data about infrastructure add to the uncertainty in assessing the current state or planning for future requirements. The paper concludes that energy transportation infrastructure should become a national priority in the interests of economic security and national security.

Paper #13: Liquefied Natural Gas (LNG) ✦

Liquefied natural gas is gas that has been cooled as a liquid for transport when pipelines are not economically or otherwise feasible. This paper describes the principal elements of the global LNG trade, defines the LNG "value chain," and assesses the prospects of emerging LNG exporters and consumers.

Paper #14: Non-Bio Renewables ✦

This paper surveys the economic, technical, and policy prospects for non-bio renewable energy sources, including wind, solar, tidal, and geothermal power. Although these energy sources do not produce liquid fuels that compete with petroleum products, they all generate electricity or heat that can displace hydrocarbon power sources such as natural gas or coal. While each renewable source has unique features, they all share such characteristics as high construction or installation costs but low operating costs. The paper discusses these characteristics and their implications for potential timing, scale, and rate of adoption of renewable energy sources.

Paper #15: Summary Discussions on Peak Oil ✦

This paper defines "peak oil" as one class of oil production forecasts and summarizes the arguments made for this point of view. The paper is based on two teleconferences with peak-oil forecasters, and a third teleconference with forecasters who do not share their view. The paper describes key concepts and indicators for the peak-oil position, including new field discoveries, production maxima in some oil-producing countries, and the inability of some producing countries to meet both domestic and export demand. The report concludes that concerns about supply shortfalls due to post-peak production have merit and warrant further consideration. It also warns that inconsistent definitions and reporting of production and reserve data raise uncertainty in supply forecasts.

Paper #16: Refining and Manufacturing ✦

This paper addresses questions about the refining capacity that will be needed over the next 25 years; the location of that capacity; the technology required to process unconventional feedstock; and policy or regulatory issues that inhibit new refining capacity. The paper concludes that all projections for 2015 show that primary oil demand will exceed projected refining capacity, even assuming that all announced refinery expansion projects are implemented. Growing oil demand in the United States is projected to outpace the increase in domestic refining capacity, leading to increased imports of finished products. Increasing technical complexity, regulatory requirements, and lengthy permitting procedures will have a combined effect on capacity expansion.

Technology Task Group

Paper #17: Carbon Capture and Sequestration (CCS) ✦

It is likely that the world is moving into an era of carbon management involving several measures to reduce CO_2 emissions, including improvements in the efficiency of energy use and the use of alternatives to fossil fuels such as biofuels, solar, wind, and nuclear power. However, to meet the energy demands of the nation, the United States will continue using fossil fuels, including coal, extensively over the next 50 years or more. To do so it will be necessary to capture and sequester a large fraction of the CO_2 produced by burning these fossil fuels, as discussed in this report.

Paper #18: Coal to Liquids and Gas ✦

This Topic Report focuses on the potential of coal to liquids and coal to gas technologies, and potential advances in these conversion processes. It examines the inputs and assumptions from various publications and the range of production estimates from these technologies.

Paper #19: Conventional Oil and Gas (including Arctic and Enhanced Oil Recovery) ✦

Large volumes of technically recoverable, domestic oil resources—estimated at 400 billion barrels—remain undeveloped and are yet to be discovered, from undeveloped remaining oil in place of over a trillion barrels. This resource includes undiscovered oil, stranded light oil amenable to CO_2-EOR technologies, unconventional oil (deep heavy oil and oil sands), and new petroleum concepts, such as residual oil in reservoir transition zones. The status of these resources is the topic of this report.

Paper #20: Deepwater ✦

Deepwater oil and natural gas resources are conventional reserves in an unconventional setting. The Topic Report describes the top priority deepwater-specific technological challenges. These are reservoir characterization, extended system architecture, high-pressure and high-temperature (HPHT) completion systems, and metocean (meteorological and subsurface) forecasting and systems analysis.

Paper #21: Exploration Technology ✦

The exploration topic study group identified five core exploration technology areas in which future developments have the potential to significantly impact exploration results over the next 25 years. These areas are seismic technologies, controlled source electromagnetism, interpretation technology, earth-systems modeling, and subsurface measurements. The Topic Report describes these and other aspects of exploration technology.

Paper #22: Heavy Oil ✦

Heavy oil, extra-heavy oil, and bitumen are unconventional oil resources that are characterized by high viscosity (resistance to flow) and high density compared to conventional oil. Production methods currently in use and those needed in the future are described in the Topic Report.

Paper #23: Human Resources ✦

The majority of oil and natural gas industry professionals are less than ten years from retirement eligibility. There are fewer academic departments in petrotechnical areas now than 20 years ago, and significantly fewer petrotechnical students are being trained to replace upcoming retirees. The upcoming demographic shift in employees is described in the Topic Report.

Paper #24: Hydrates ✦

Gas hydrates are found within and under permafrost in arctic regions, and also within a few hundred meters of the seafloor on continental slopes and in deep seas and lakes. The reservoir architecture, technology needs, and eventual economic importance of hydrates in arctic and marine environments may be very different. Arctic hydrates lack validated methods for economical production, but for marine hydrate resources the added challenge is even more fundamental: a validated means of reliably finding them in significant deposits.

Paper #25: Nuclear Power ✦

Nuclear power is expected to have a greater impact on use of coal rather than oil or natural gas, because it provides base-load power. This Topic Report discusses the predictions of future nuclear power usage.

Paper #26: Oil and Gas Technology Development ✦

Since the beginning of the modern age of oil and natural gas, technology has played a fundamental role in supporting the efficient production of hydrocarbons. Payoff from a new technology can be huge, both for the individual company and for national energy security. However, commercializing technology in the oil and gas market is costly and time intensive; with an average of 16 years from concept to widespread commercial adoption. The Topic Report describes the technology development process.

Paper #27: Oil Shales ✦

Globally, it is estimated that there are roughly 3 trillion barrels of shale oil in place, which is comparable to the original world endowment of conventional oil. About half of this immense total is found near the common borders of Wyoming, Utah, and Colorado. The Topic Report describes very recent advances in recovering this resource and the additional challenges ahead.

Paper #28: Transportation Efficiency ✦

Improved efficiency in transportation can have a significant influence on future energy usage. This report examines several studies on transportation technologies and discusses the efficiency gains to be obtained in segments of light-duty vehicles, heavy-duty vehicles, air transport, marine shipping, and rail transport.

Paper #29: Unconventional Gas ✦

Unconventional natural gas resources constitute some of the largest components of remaining natural gas resources in the United States. The Topic Report describes in detail tight sand, coalbed methane, and gas shale resources, and discusses advances needed in these areas.

Geopolitics & Policy Task Group

Paper #30: Historical Perspective on Energy Crises and U.S. Policy Responses ✦

Section I excerpted from 1987 NPC Report, *Factors Affecting U.S. Oil & Gas Outlook.*

Macroeconomic Subgroup Reference Reports

Paper #31: Energy Markets Grow Up: How the Changing Balance of Participation Influences Oil Price, Katherine Spector, 6/15/05 ✦

This report explores who trades financial energy today, and how they participate in the market. The increase in the number of would-be buyers of energy over the past few years—including energy consumers, fundamentally inspired speculators, and passive investors—coincided, as prices rose, with a marked decline in hedging by producers, the market's natural sellers. The result is a sharp increase in the competition for forward price that has changed the way the market responds to bullish energy fundamentals.

Paper #32: Energy Markets Grow Up Part II: Who Trades Energy Now and How Much Does It Matter? Katherine Spector, 1/8/07 ✦

This is the follow-up report to "Energy Markets Grow Up: How the Changing Balance of Energy Market Participation Influences Price," a report which looked at who trades energy and why, and explained how the development of the financial energy market has changed the path of not only energy prices, but the shape of the futures curve and volatility. This report updates that discussion, examines what has changed in the past year, and—in a market with so little hard data on money flows—attempts to quantify the role that some of these market participants play. Specifically, this report estimates the per-commodity inflows and outflows associated with index investment on a quarterly basis since 2002. This report attempts to isolate the flow of money from rebalancing pure index positions to maintain fixed allocations to commodities. The report also explores some of the strategies that investors are using to improve returns—and that banks are using to manage the risk associated with selling index style products to real money customers.

Paper #33: Oil Shocks and the Global Business Cycle, David Hensley, 5/12/06 ✦

This report examines the increase in oil prices in the 1970s and the increase in oil prices in the 2000s and identifies the factors that contributed to the different outcomes in the two periods, including the difference in energy intensity, the rapidity of the price rise, and geopolitical tensions.

Paper #34: The Good, the Bad and the Ugly about the Oil Shock Impact on Emerging Markets, Luis Oganes & Katherine Spector, 10/21/05 ✦

This report examines the impact of the increase in oil prices seen in 2003–2005 on net oil exporters in Emerging Market.

Paper #35: Three Propositions on the Economics of Greenhouse-Gas Regulation, Marc Levinson, 2/14/07 ✦

This presentation was presented by Marc Levinson at the NPC Carbon Management meeting on February 14, 2007 in Princeton. Three propositions about climate change include: (1) If greenhouse-gas emissions cause social harm, emitters should bear a cost intended to discourage emissions; (2) Although it is impossible to calculate an "optimal" cost of emissions, the cost must be high enough to discourage consumption of greenhouse-gas-intensive goods and services; (3) The real cost of emissions should rise on a predictable path over an extended period of time, as extremely sharp or erratic price changes have the potential to cause significant economic harm.

Paper #36: Capturing the Gains from Carbon Capture, Marc Levinson, 4/11/07 ✦

Carbon sequestration—the burying of carbon dioxide captured from power generation and manufacturing—is likely to develop into an extremely large industry in the face of mounting concern about climate change. Investor interest in climate change has so far centered on utilities and fossil-fuel producers. This report seeks to widen this focus and look at opportunities for the industrial companies that are staking out roles in the infant capture-and-sequestration industry.

Paper #37: Carbon Dioxide: A Commodity Market Perspective, Scott Speaker, 3/27/07 ✦

This report intends to assess the emerging risks and opportunities of impending regulation of carbon dioxide emissions from U.S. power generators and heavy industries from a commodity market perspective and quantify potential impacts where possible.

Paper #38: All You Ever Wanted to Know About Carbon Trading, January 2007 ✦

This report provides an introduction to carbon trading and examines the emerging risks and opportunities of impending regulation of carbon dioxide emissions.

STUDY DATA WAREHOUSE FILES

To make the study's broad-ranging and original sources easily available to all participants, a data warehouse was developed. This provided for centralized management of the multidimensional data collected. By the time it concluded, the study had compiled and used nearly 100 energy forecasts or outlooks. These forecasts and several hundreds of papers/documents on various aspects of the energy sector were used in the interpretations that formed the basis of the study findings and recommendations.

The data warehouse was designed to be the main analytical tool for the Task Groups, accepting all data collected from the survey questionnaire and other data sources. Once in the data warehouse, selected values or ranges of values for any or all dimensions could be applied as a filter to enable analysis.

As with the Topic Papers, the National Petroleum Council has not endorsed or approved the contents of the study's Data Warehouse but approved making available this information as part of the study process.

The NPC believes that the information in the Data Warehouse will be of interest to the readers of the report and will help them better understand the study results. The structured data used in the NPC study, along with software to display data and graphics, are being made available in the interest of transparency.

ACRONYMS AND ABBREVIATIONS

ACEE	American Council for an Energy-Efficient Economy
AEO	*Annual Energy Outlook* (annual publication from EIA)
AIChE	American Institute of Chemical Engineers
ANWR	Arctic National Wildlife Refuge
APEC	Asia-Pacific Economic Cooperation (a group of energy ministers from 21 countries)
ASPO	Association for the Study of Peak Oil
Btu	British thermal unit
CAFE	Corporate Average Fuel Economy
CBM	coalbed methane
CCS	carbon capture and sequestration
CCSP	U.S. Climate Change Science Program
CHP	combined heat and power
CO_2	carbon dioxide
CSEM	controlled source electromagnetism
CSS	cyclic steam stimulation
CTG	coal-to-gas
CTL	coal-to-liquids
EC	European Commission (see also WETO)
DOE	U.S. Department of Energy
E&P	exploration and production
EOR	enhanced oil recovery
EIA	DOE's Energy Information Administration
EPRI	Electric Power Research Institute
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
GTL	gas-to-liquids
HOV	high-occupancy vehicle
HVAC	heating-ventilation-air conditioning systems
IEA	International Energy Agency
IEO	*International Energy Outlook* (annual publication from EIA)
IGCC	integrated gasification combined cycle
IOCs	international oil companies
IOGCC	Interstate Oil and Gas Compact Commission
IPCC	Intergovernmental Panel on Climate Change
LDV	light duty vehicle
LNG	liquefied natural gas
MB/D	million barrels per day
mpg	miles per gallon
MMS	U.S. Minerals Management Service

NAFTA	North American Free Trade Agreement
NGL	natural gas liquid
NIMBY	not in my back yard
NGOs	non-governmental organizations
NOCs	national oil companies
NOx	nitrogen oxides
NPC	National Petroleum Council
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of Petroleum Exporting Countries
PDVSA	Petroleos de Venezuela (Venezuela's national oil company)
ppmv	parts per million by volume
PPP	purchasing power parity
Quad	quadrillion Btu
RECS	EIA's Residential Energy Consumption Survey
R&D	research and development
R/P	reserves-to-production
RPSEA	Research Partnership for a Secure Energy America
SAGD	steam-assisted gravity drainage
SPR	Strategic Petroleum Reserve
SSEB	Southern States Energy Board
TCF	trillion cubic feet
URR	ultimately recoverable resources
USGS	United States Geological Survey
WEC	World Energy Council
WEO	*World Energy Outlook* (annual publication from IEA)
WETO	*World Energy Technology Outlook 2050* (published in 2006 by European Commission)
WETO-H2	WETO Hydrogen Case
WTO	World Trade Organization

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***Note:** A detailed glossary of terms used in this report is available at www.npc.org and on the CD that accompanies the printed report.*

CONVERSION FACTORS

1 barrel = 42 U.S. gallons = 159 liters = 0.16 cubic meters (m^3)

1 cubic foot = 0.028 cubic meters (m^3)

1 cubic meter (m^3) = 35.7 cubic feet

1 short ton = 0.91 metric tons

1 metric ton = 1.1 cubic feet

APPROXIMATE BTU CONTENT[1]

100 million metric tons of oil equivalent = 4 quadrillion Btu

1 quadrillion Btu = 25.2 million metric tons of oil equivalent

1 barrel of crude oil = 6.0 million Btu

1 million barrels of oil per day = 2.12 quadrillion Btu per year

1 cubic foot of natural gas = 1,030 Btu

1 billion cubic feet per day = 0.38 quadrillion Btu per year

1 short ton of coal = 20.3 million Btu

1 million short tons of coal per day = 7.4 quadrillion Btu per year

1 gigawatt-bour of electricity = 3,412 million Btu

2,400 gigawatt-hours of electricity per day = 3 quadrillion Btu per year

1 barrel of motor gasoline = 5.2 million Btu

1 barrel of distillate fuel = 5.8 million Btu

1 barrel of residual fuel oil = 6.3 million Btu

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[1] Actual heat values vary over time and by source. The values shown are an approximation.